MAY, 1961

Welding Journal

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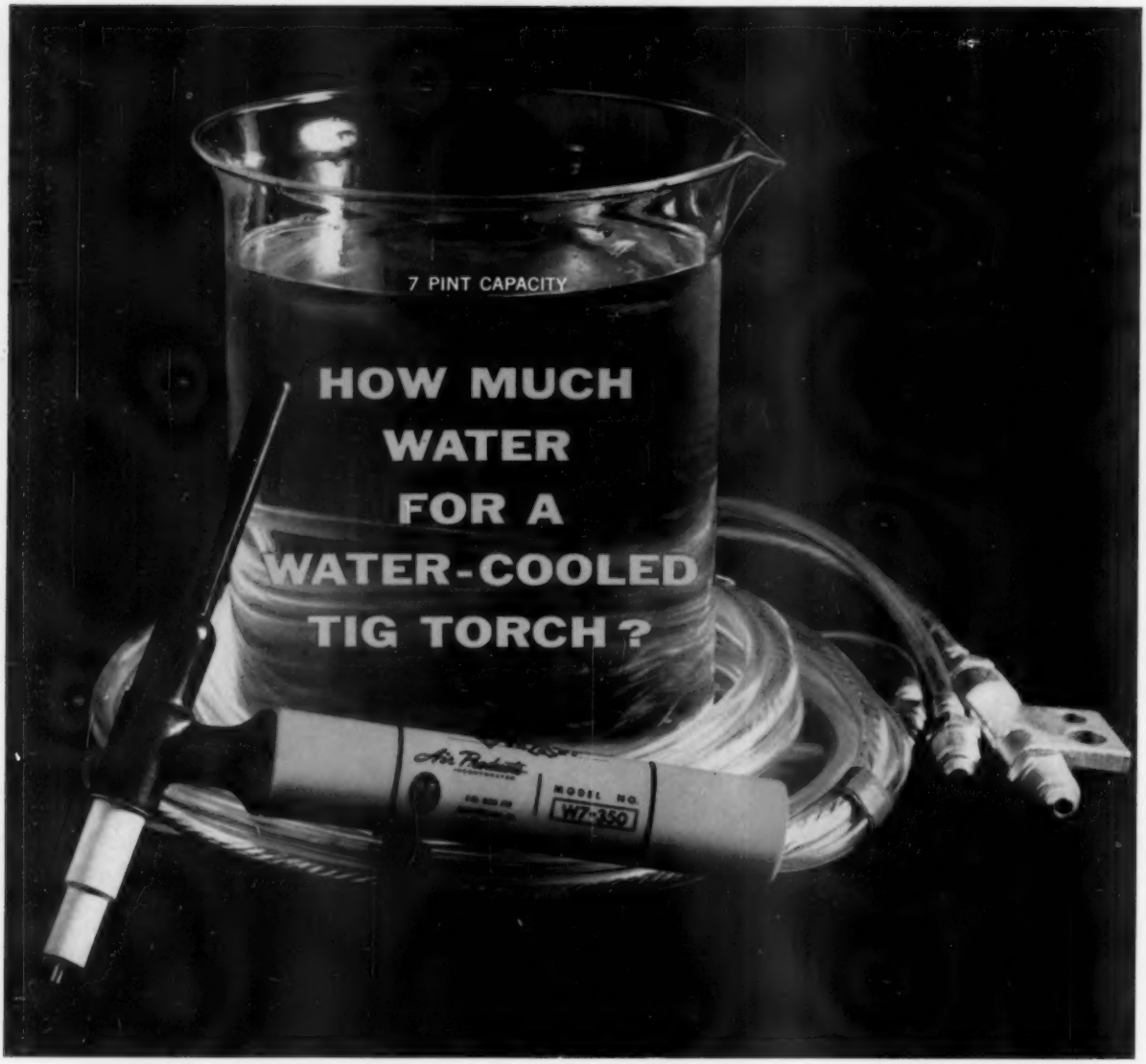
OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



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PRESS-TIME NEWS ... about ... People ... Welding ... Products

Olin Dedicates Research Center

New welding facilities were among highlights of an Olin Mathieson Chemical Corp. dedication of its $7,500,000 research center in New Haven, Conn., recently. Additional highlights included announcement of a breakthrough in the search for a commercially practical way to make aluminum from common clay and demonstration of a new plastic which can stop bullets and which, when fashioned into bars with sharpened points, can be hammered through metal.

Speakers at the dedication included R. C. Lee, mayor of New Haven, who proclaimed New Haven Research Week. In his remarks, Mayor Lee stressed the beneficial impact of Olin on the city's economy as measured by the $30,000,000 which Olin pays annually to its New Haven employees. Other speakers included Stanley de J. Osborne, president of the corporation, who announced the establishment of Olin Awards for Scientific Achievement for employees.

Olin sales in 1960 were $689,623,000. At the same time, Olin expanded $23,800,000 for research under the administration of W. E. Hanford, vice president for research.

Burdett Oxygen Sells California Plant

The Burdett Oxygen Co. of Cleveland, Ohio—fifth largest producer of industrial gases in the USA—recently announced the sale of its operations in Sante Fe Springs, Calif., to American Cryogenics Co., Augusta, Ga., for $2,525,417.

According to W. H. Loveman, president of Burdett, proceeds from the sale will be used to launch an expansion program in the Midwest.

WELDING FACILITIES AT OLIN RESEARCH CENTER

I. A. MacArthur, right, describes demonstration of gas-metal-arc spot welding on aluminum to families of Olin employes at Research Center dedication in New Haven. Welding facilities include electron beam unit for aircraft alloy investigations and both gas tungsten-arc and gas metal-arc equipment for aluminum, brass and copper welding investigations.

O. B. J. FRASER RETIRES

A member of AWS since 1935 and a former president of the SOCIETY, O. B. J. Fraser, formerly assistant manager of the Development and Research Div., International Nickel Co., New York, N. Y., retired recently.

Gains for Cryogenics

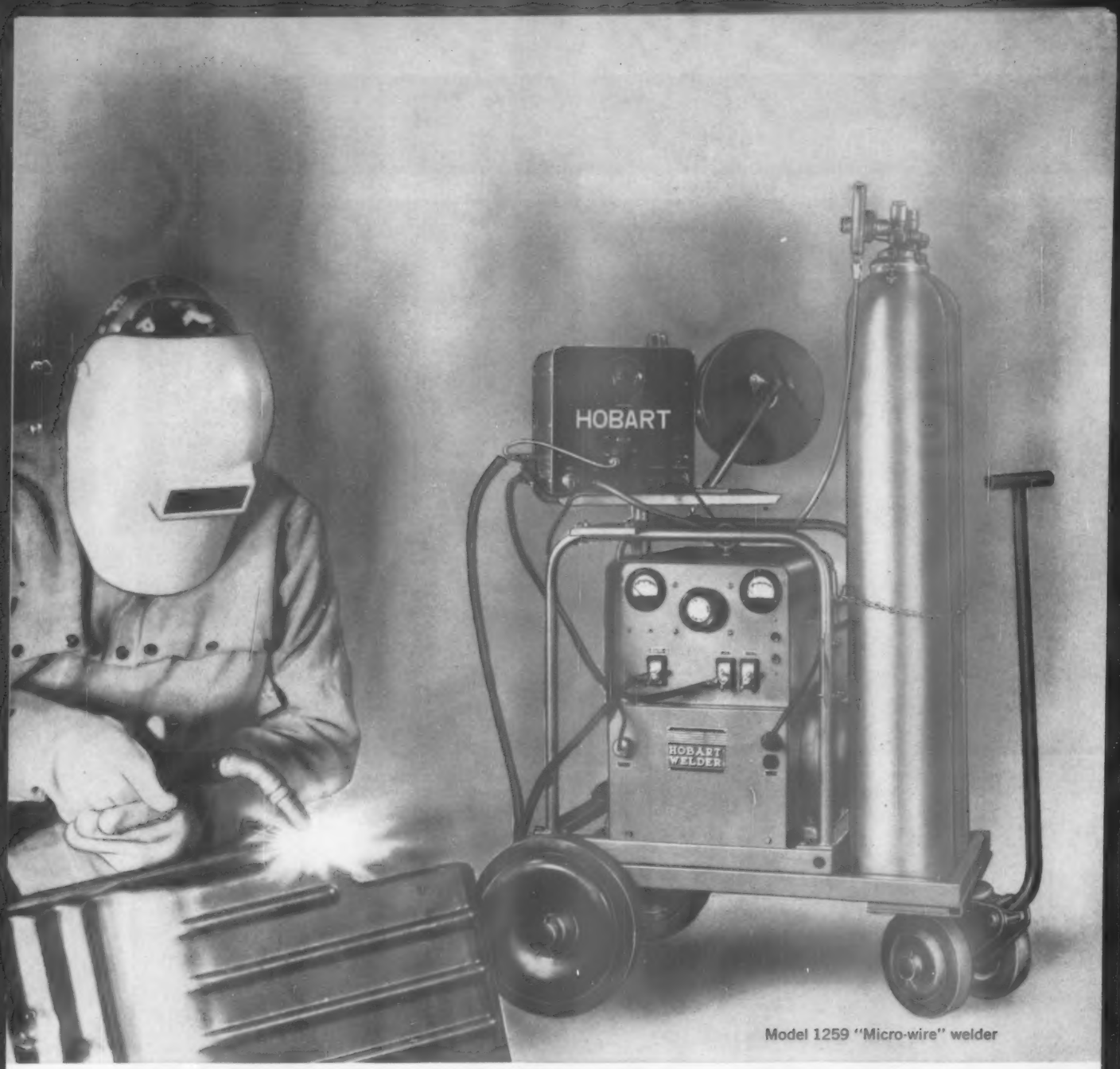
The commercial production of industrial gases and cryogenic products chalked up record increases last year, according to W. B. Nicholson, president of Linde Co., Div. of Union Carbide Corp.

"We estimate total domestic sales of the industry reached $518 million in 1960," said Mr. Nicholson. "From all indications, we expect this market to reach the $650-million-per-year level by 1964."

Burrill Delivers SNT Honor Lecture

E. Alfred Burrill, vice president and director of marketing, High Voltage Engineering Corp., Burlington, Mass., recently delivered the Lester Honor Lecture at the Fifth Western States Convention of the Society for Non-destructive Testing in Los Angeles, Calif. This lecture is presented biennially by some outstanding person on a subject with a direct bearing on the use of X-rays to inspect materials for civilian and military use.

The title of Burrill's lecture was "High - Energy Nuclear Radiations—Their Implications for Industry." He discussed the effect of the nuclear particle accelerator upon modern scientific research and industrial technology.



Model 1259 "Micro-wire" welder

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That's Hobart's new MICRO-WIRE welder package. Think what this means in cutting costs! No time loss changing electrodes—no stub end loss—no clean up of welds necessary. Joins sheet metal and heavier sections, using small diameter wire and inexpensive carbon dioxide (CO_2) or argon and CO_2 mixtures. Actual production economies will amaze you. This new MICRO-WIRE package is an extremely versatile unit for all position welding and can be used by inexperienced as well as experienced operators. For complete details, write for bulletin DM-159.

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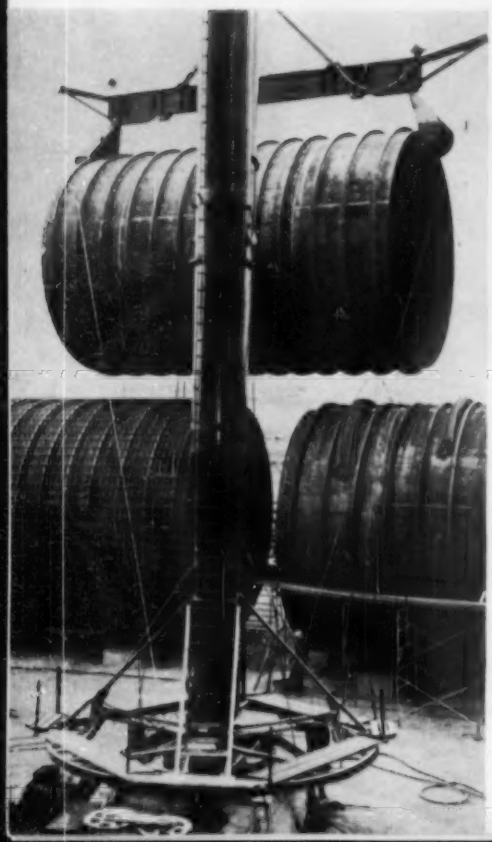
WELDING ZONES

Welding fabrication of a liquid oxygen tank at the Struthers Wells Corporation's Warren, Pa., plant

Large multilayer pressure vessels such as the one shown are being X-rayed by A. O. Smith Corporation's new 6000 roentgen per minute linear accelerator



(Above) Giant steel "cans" make an automobile appear almost toylike. The 24-ft diam steel sections will line seven hydroelectric-power tunnels at Oahe Dam, now under construction near Pierre, S. D.

(Left) It will take 449 of these "cans" to channel waters of the Missouri River through the tunnels in the Oahe Dam (Courtesy U. S. Steel Co.)

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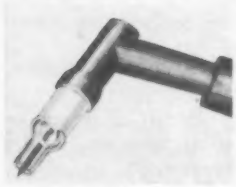
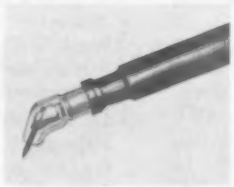
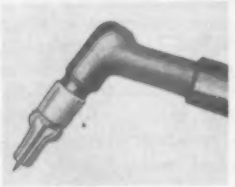


TEC Watercooled Angle Torch



TEC Watercooled Pencil Torch



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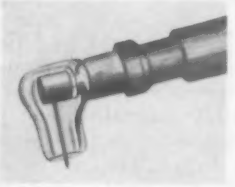

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

BELGIUM

The June 1960 issue of *Acier Stahl Steel* from Belgium describes the air tight steel pressure vessels of the materials testing reactor and pressurized-water power reactor built at the Belgian nuclear training center. The design involved full penetration joints throughout. A normalized silicon-killed steel containing 1% Mn and 0.18% C max was used.

This issue also contains details of two welded tubular structures: the roof of the Sports Stadium Milan, Italy, and the pylons of a transmission line in France.

EAST GERMANY

The East German magazine *Schweisstechnik* for July 1960 contains two papers on economic factors in production welding. Both papers concentrate on automatic welding, particularly submerged arc. One paper is a general discussion, while the second deals with railway-car fabrication.

POLAND

The Welding Division of the Polish Mechanical Engineer's Society publishes a monthly journal entitled *Przeglad Spawalnictwa*, edited by Edward A. Juffy. The first six issues of 1960 contained the following articles of general interest:

January: A New Hypothesis on Hydrogen and Porosity in Welds, and Fatigue Tests on Flat Steel Bars with Welded Gussets.

February: Arc and Resistance Welding in Railway Passenger Car Construction, Flux Recovery in Submerged-arc Welding, and Multiple-electrode Spot Welder for Wire Mesh.

March: Continuation of the first two articles of February.

April: Hard Facing of Blast Furnace Bells, and Welded Stainless Steel Bottom for an Arc Furnace.

May: Pressure Tests in Welded Piping Containing 0.11–0.18 C, 0.4–0.7 Mn, 0.17–0.37 Si, 0.8–1.1 Cr and 0.4–0.6 Mo, and AS-9 Electrode Welder.

June: Bead-on-plate Tests on Low-alloy Steel, Welded Steel Arch Bridge with Orthotropic Roadway in Belgrade, and Calculating Peak Temperatures in Welded Joints.

SWITZERLAND

A novel means of seam resistance welding tin cans which avoids contamination of the rollers was described in the June 1960 issue of the Swiss *Journal de la Soudure*. A copper wire from a spool passes over each roller to make the actual contact with the tin-coated steel. The wire is used only once. Sheet 0.012 in. thick was welded at 390 ipm with a 10 kva machine.

Pipe Manufacture

The Swiss magazine *Zeitschrift für Schweisstechnik* in its August 1960 issue describes a plant built in 1956 for the manufacture of spiral-joint pipe made from cold-rolled strip 0.032- to 0.047-in. thick. The pipe is $5^1/_4$- to $6^1/_4$-in. OD, and is resistance-lap-seam welded. For spiral welded pipe 0.039- to 0.32-in. wall, $5^1/_4$- to $16^1/_2$-in. OD hot-rolled strip is used with submerged-arc welding. In one shift, 120 tons per month has been produced. Arrangements are being made to produce aluminum, copper, stainless steel, and zirconium spiral-welded pipe using argon-arc welding in this plant located in Düdingen, Switzerland.

USSR

The June 1960 issue of *Svarachnoe Proizvodstvo* the Russian production welding magazine consists principally of articles on mechanization of welding.

- A productivity coefficient is defined which ranges from one to eight and is based on the degrees of mechanization. The coefficient ranges from unity for manual work to eight for an automatic welding line with conveyor. Several highly mechanized welding machines are illustrated, including a machine to surface pilger mill rolls, and another to weld gas spheres with CO_2.
- Illustrates several automatic arc and multiple spot welders.
- Specifications of thirty Russian welding positioners.
- Automatic submerged-arc setup for welding tank cars 2100 cu ft capacity.
- Assembly line for welded broaching machines.
- Automatic welding setups for agricultural machinery.
- Several submerged-arc welding setups are described.
- Automatic submerged-arc welding for side sheets of hopper cars (travel speed 30 to 35 ipm).
- Automatic submerged-arc welding of spiral lap joint pipe $^1/_{16}$-in. wall, 7 in. diam, at a travel speed of 46 ipm.
- Assembly line for welding dump truck bodies.
- Automatic submerged-arc welding of tractor frames.
- Layout and circuit diagram of automatic submerged-arc welder for air reservoirs, $^1/_4$ in. thick, 10 to 20 in. diam.
- Description of a toroid to measure current in resistance welding and an instrument to modulate the wave form.
- Revisions have been made to Russian Standard GOST 2523–51 on arc-welding electrodes. Four types of electrode coverings are involved: organic, rutile, 6020 and lime-fluorspar. The requirements that have been revised include mechanical properties, concentricity and chemical analysis.
- The new Russian Standard GOST 2246–60 for automatic arc-welding wire for steel includes 56 types of

DR. GERARD E. CLAUSSEN is associated with Arcrods Corp., Sparrows Point, Md.

No danger to these welds from hydrogen embrittlement. They're produced with Inco-Weld "A"; carbon steel flanges to stainless steel jacket, stainless steel jacket to Inconel* nickel-chromium alloy plate.

Inconel alloy to stainless steel to carbon steel ...Versatile Inco-Weld "A" Wire joins all 3

This retort is destined for brazing and bright annealing at working temperatures up to 2100°F in dry hydrogen atmosphere.

The welding problem was to obtain joints between three dissimilar metals: Inconel alloy, stainless steel, and carbon steel. These joints had to resist oxidation, resist cracking due to hydrogen embrittlement, and at the same time remain strong at high temperatures.

Rolock, Inc. of Fairfield, Connecticut, produced the desired welds with a *single* material, Inco-Weld "A"* wire. This wire, it has been demonstrated, will produce X-ray quality welds between 97% of all weldable dissimilar alloy combinations. What's more, the Inco-Weld "A" deposit matches (or betters) the heat and corrosion resistance of most parent metals. Other advantages include:

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steel wire. Dimensional tolerances and spool sizes are given.

Automatic Welding

Avtomaticheskaya Svarka contains the following articles of general interest in its June 1960 issue:

- A machine is described for friction welding concrete reinforcing bars $^5/_8$ to $^7/_8$ in. diam. Relative speed of rotation = 1450 rpm; pressure during hearing and forging = 6500 psi; push up = $^1/_8$ in; time = 6 to 9 sec; maximum power = 24,300 w per sq in. of cross section.
- Series condensers in spot-welding transformers lower wattage loss by a factor of 1.5 to 2.5, and relieve flicker troubles in feeder lines. However, power adjustments must be made by changing taps on the transformer, because changes in the ignition angle of the ignitrons beyond 20 to 25 seriously increase the power factor. By decreasing machine resistance, condensers improve spot-weld quality.
- Electroslag welding was used to weld a 32 ft diam sphere of 0.95 in. thick steel plates.
- Tungsten arc welding with magnetic stabilization of the arc was used to weld a plug into the end of a tube $^3/_{16}$ in. diam (similar to cone arc welding).
- To weld 80Ni–20Cr castings 1 in. thick without hot cracks and with good slag removal, a covered electrode is recommended, the core rod of which contains 24 Cr, 14 W. The covering is limestone and fluorspar with a Ni-Mn alloy containing 15% Mg.
- An automatic CO_2-welding jig is described for welding flanges to mild steel pipe 1 in. diam, $^1/_8$ in. wall.
- A standard model condenser discharge welding machine (300 volt-amperes) is described.
- For multiple electrode spot welders the multiple transformer system is preferred with the secondaries consisting of a single loop.
- To weld the copper lining $^1/_2$-in. thick of a rectifying column, helium or helium-nitrogen mixture was used as a protective gas with a copper alloy electrode containing 3% Si, 1% Mn.

WEST GERMANY

The West German magazine *Schweissen und Schneiden* for June 1960 contains three articles on structural welding. The first describes the replacement of parts of a curved plate girder railway bridge built in 1912 by parts welded of mild steel with rutile electrodes and for root passes, low-hydrogen electrodes. The second article describes an all-welded deck-truss three-span railway bridge put into operation in 1959, the center span of which is 120 ft long. Formulas are given for calculating secondary stresses, which could not be neglected. The truss members are of box section, molded together at intersections to avoid the stress concentrations associated with gusset plates. The third article describes fixtures for welding plate girders and tubular masts.

Also in this issue is a long article on flame-cutting machines in shipyards. Magnetic roller, photoelectric and gantry type machines are described as well as the principles of pattern making. The scheduling of work and the economics of flame cutting are discussed.

This issue contains new German Standard DW8553 on butt joint designs for clad steels.

The Welding Design Committee of the West German Welding Society issued its third paper, which deals with welded columns. Two graphs show the decrease in allowable stress with increase in slenderness ratio, while 42 sketches show column designs.

A reprint from the German magazine, *Plate*, reviews the requirements for steel strip for manufacture into welded pipe.

Welding Education

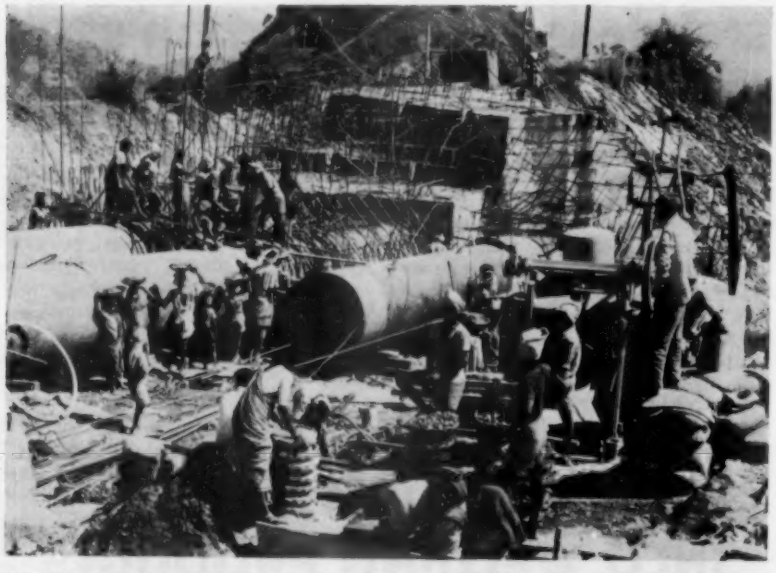
The West German *Schweissen und Schneiden* contained the following general articles in its August 1960 issue:

There are eight combination welding schools and welding research institutes in West Germany. Four are self-supporting; four are supported by the cities in which they have been established. At the end of 1958 the eight institutes employed 162 people, of which 35 were engineers and 50 were welding instructors. In that year there were 10,000 students, and 392 welding engineers were certified. The welding engineer's course involves 240 hr of day and evening instruction.

A report of the German boiler society records the results of tests on carbon diffusion, high nickel battered layers and cyclic temperature variation on welds between austenitic and ferritic steam piping. The most expensive but most satisfactory joint was made by inserting a shop welded section machined externally and internally to remove all notches. The section consisted of an austenitic ring welded to a ferritic ring by either of two methods: (*a*) with a high nickel weld metal (Inco Weld or Hastelloy W) or (*b*) with a columbium-stabilized austenitic electrode.

A brief description is given of products exhibited by welding firms at the 1960 Hanover Industrial Fair.

INDIA



Hindu workmen pour concrete for one of 21 anchor blocks for T-1 steel penstock fabricated and welded by Davie Shipbuilding Ltd., General Engineering Div. at the Kundah hydro electric project in Madras, South India. (Courtesy Canadian Liquid Air Co.)

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Adequate Versus Perfect Welding

In recent years the welding industry has been called upon to deliver the utmost in quality in order to satisfy the design and safety requirements of the many high performance applications of welding encountered in some of the new systems and equipment of our present age.

These requirements for excellence have been met by assiduous attention to the details of welding technique, by very extensive training of welding and supervisory personnel, and by the establishment of stringent quality control and inspection procedures.

As a result we have in this country a large pool of highly-knowledgable engineers and of highly-skilled welders, technicians and supervisors. In the course of time these people come to regard the degree of perfection demanded by this "super" quality class of work as being the order of the day, and having developed an ingrained awareness for highest quality, accept as commonplace the rigid standards required by the critical nature of an increasing percentage of today's welded products.

We have profited from learning methods by which perfect and near-perfect welds can be achieved. However, it is also true that the high degree of excellence demanded for the more exacting services has necessitated procedures which are extremely slow and expensive. Such excellence has not been, and is not now, needed for average and production run welded products, and in fact is not in keeping with practical and economical engineering concepts for the great bulk of our work. We should exercise great care that perfection where it is not required does not become a false goal simply because it is attainable or has become a habit. In order for welding to continue its phenomenal increase in usefulness we must continually guard against shackling its economic advantages by applying unjustifiably stringent standards.

The AMERICAN WELDING SOCIETY has exerted a powerful influence toward rationalization by its continued development of specifications and standards based on actual requirements for the various classes of welded products, avoiding excesses where they are not warranted, while preserving excellence where it is essential. Industry looks to AWS to preserve this balance.

D. A. Holden

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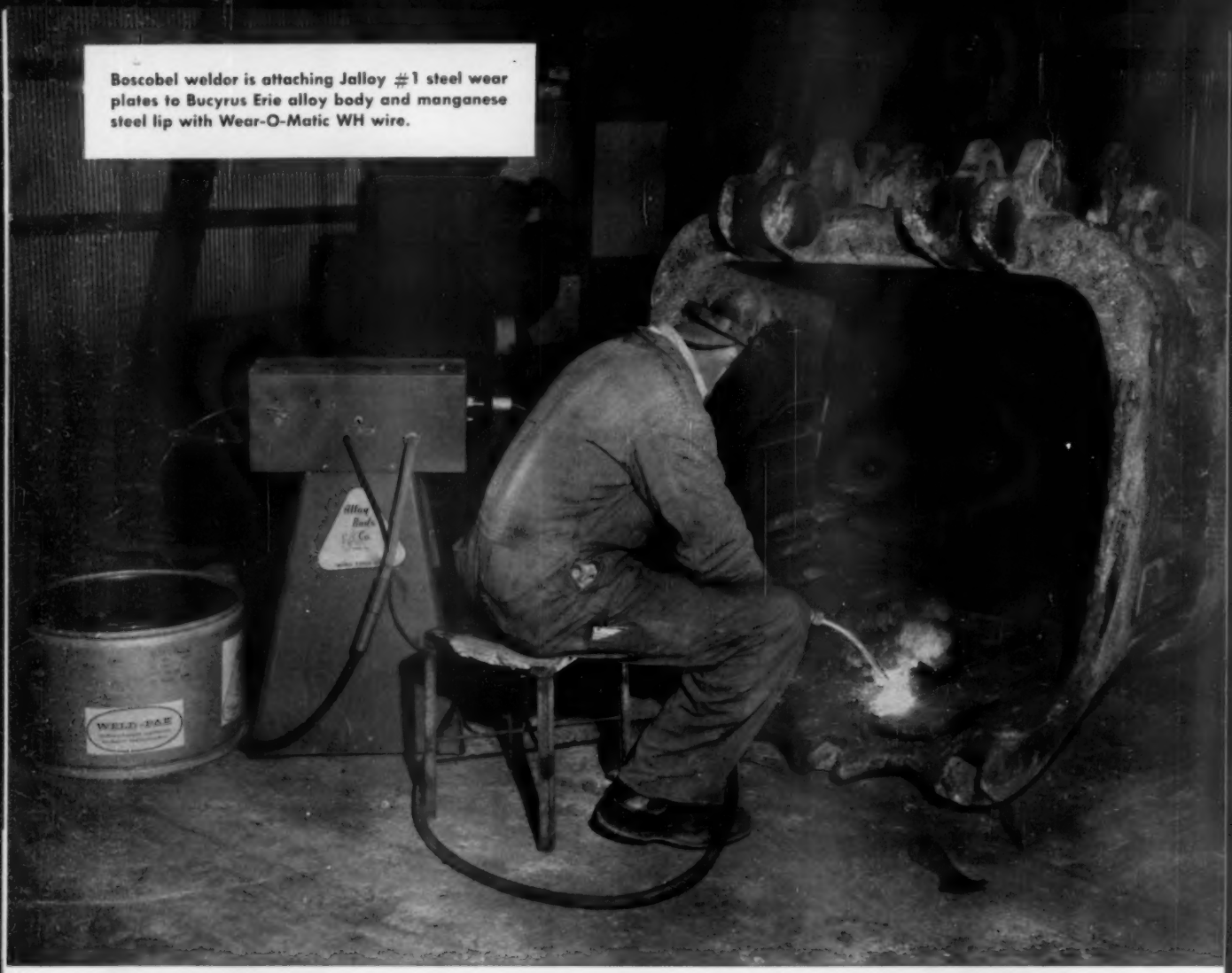

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TWENTY YEARS OF LEADERSHIP IN THE DEVELOPMENT OF QUALITY ALLOY ARC WELDING ELECTRODES

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Nearly completed public auditorium in Pittsburgh, Pa., with 13,600 seating capacity

Pittsburgh Public Auditorium
Retractable Roof

for weatherproof enclosure can be quickly opened to provide spectacular open-air stadium to accommodate 13,600 persons

BY E. COHEN AND R. H. GOLDSMITH

SYNOPSIS. The design of the roof for the nearly completed public auditorium in Pittsburgh, Pa., is described with special attention to the extensive utilization of welded components and connections.

The unique feature of the auditorium is its vast retractable roof. The first such dome-like roof ever built and one of the largest clear span roofs in the world, its eight 45 deg sections or leaves (six movable and two stationary) make possible a weatherproof auditorium that can be converted to a spectacular open air stadium in $2^1/_2$ min. The configuration when closed is that of a compound spheroid nearly circular in plan, approximately 417 ft in diam, and 109 ft high at the center.

The dome has no interior supports, the leaves being supported at their bases on motorized wheel carriages. These rest on rails mounted on a reinforced concrete ring girder which is 34 ft above the arena floor. At the crown the leaves rotate on the pins of a multiple clevise mounted at the end of a space frame that cantilevers from outside the dome and terminates at the center.

The cantilever space frame, which is the main support for the leaves, is a triangular truss in both plan and cross section. The bottom chord is a curved box girder approximately 8 ft wide and 17 ft 6 in. deep embedded in a concrete abutment at the base. The top chord tie-back members are 3- x $3^1/_2$-ft box sections and extend from the achorage points up to a point on the box girder near its top. The entire cantilever space frame truss weighs about 1400 tons.

The upper joints of the cantilever space frame are formed of stress-relieved shop weldments. These weldments, connecting as many as seven large box-section members in one shop welded joint and developing all four sides of each box, are believed to be the first of their kind. The box-section members between joints are fabricated separately and connected to the weldments in the field with high-strength bolts. The joints on the lower chord are also stress-relieved shop weldments which are fastened to the box girder by field welding. The segmental arch ribs of the roof leaves, the wheel carriages, the pivot assemblies, the tie back anchors, the rail supports and numerous other elements of the structure were designed for and fabricated by welding.

All welds were inspected visually and either by radiographic or ultrasonic testing. Dye penetrant tests were made in some cases. Special procedures were developed for the main field welds in the space frame. Weldment plates were checked for lamination with ultrasonic apparatus. Computed deflections were verified by load tests on the actual structure.

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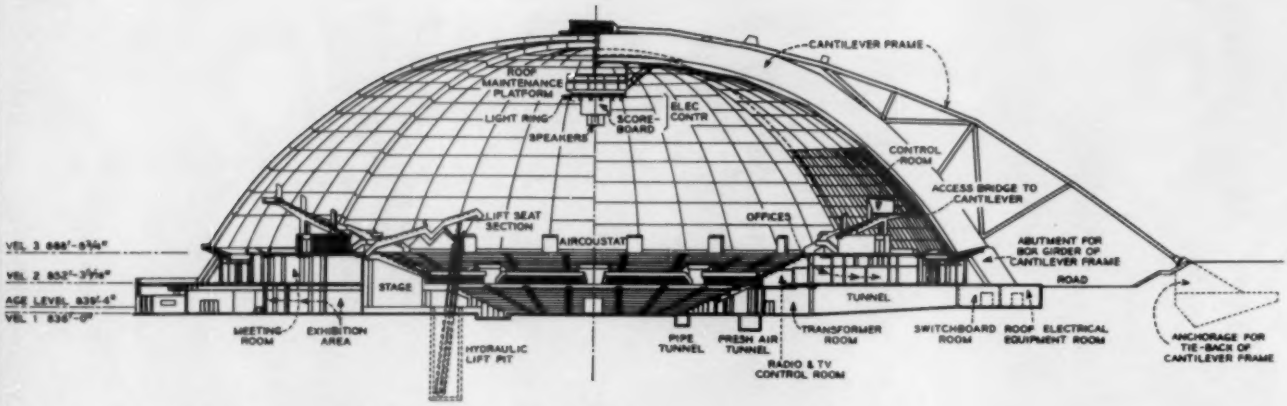


Fig. 1—Architect's drawing showing cross section of auditorium

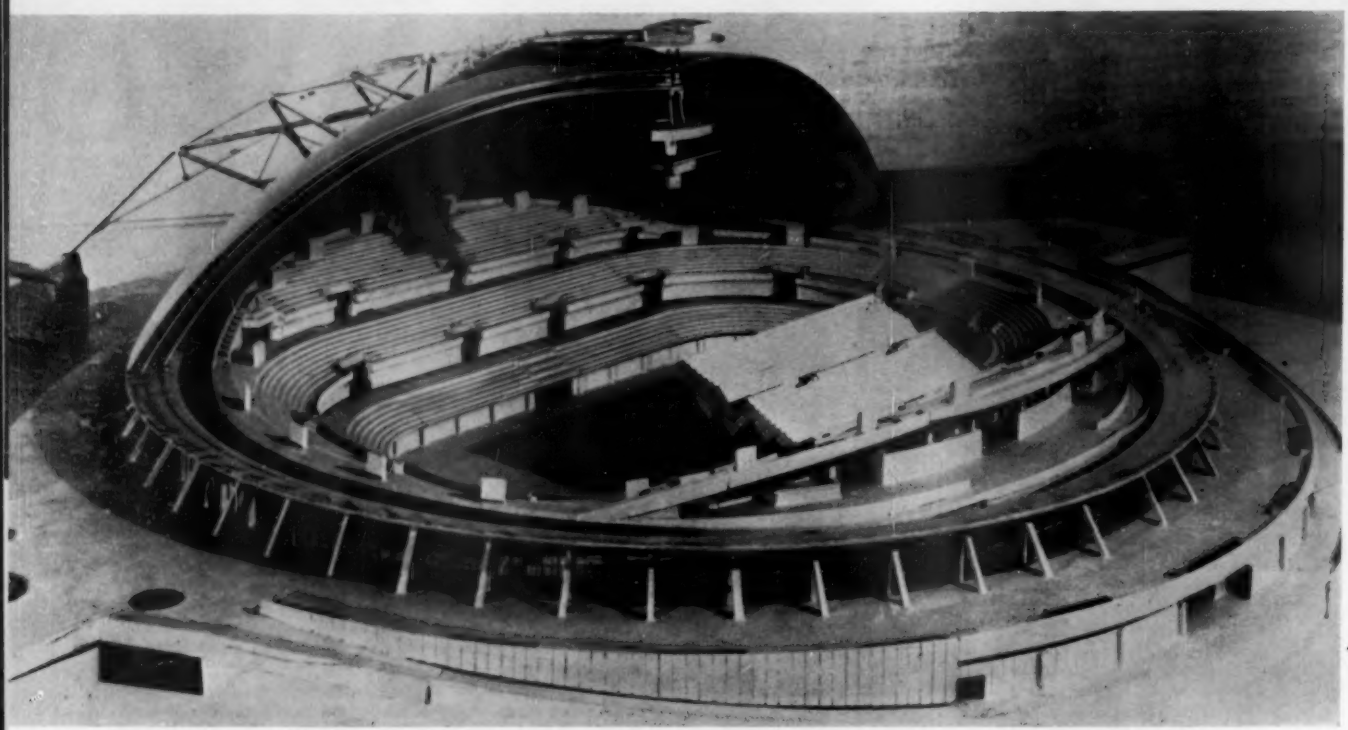


Fig. 2—Model of auditorium with roof open

General Description

The Pittsburgh public auditorium now near completion will be the key structure in Pittsburgh's Lower Hill Redevelopment. This $20,000,000 structure will be able to accommodate up to 13,600 persons. The auditorium, including mall and parking area, will occupy about 20 acres. Its diversity of equipment will permit a range of performances from grand opera to water shows, ice skating and rodeos—Fig. 1.

A unique feature of the auditorium is its vast, dome-like, retractable roof with a total surface area of 166,000 sq ft, sheathed in stainless steel. The first such roof ever built, its movable leaves make possible a weatherproof auditorium that can be converted to a spectacular open air stadium in $2^1/_2$ min—Fig. 2. Further, it is one of the largest clear span roof structures in the world, the maximum span of roof being approximately 417 ft measured from base of rails and the average rise of roof leaves, measured from pin center to base of rail, being about 109 ft—Fig. 3. The entire dome is mounted on a reinforced concrete ring girder approximately 34 ft above the arena floor. It is divided radially into eight 45-deg sections or leaves, six movable and two stationary, as shown in Fig.

Fig. 3—Interior view of partially completed and open roof

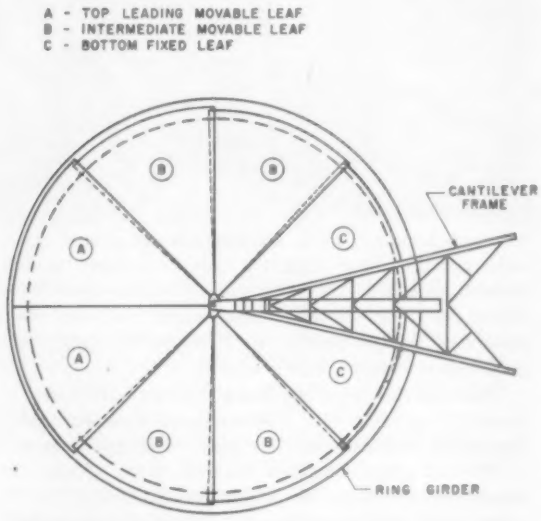


Fig. 4—Plan of roof leaves

4. To retract the roof, the six movable roof sections roll on concentric circular rails, telescope one over the other, and finally nest in sets of three over the two fixed roof sections to open the arena to the skies.

The dome has no interior supports. Instead, it is supported at its zenith by an exterior curved steel space frame of triangular cross section that cantilevers from outside the dome and terminates at the top in multiple clevises for the leaf pivot pins. The bottoms of the roof leaves rest on a series of motorized carriages which roll on steel rails anchored to the concrete ring girder.

Roof Leaves

Structural Framing

In plan view, each roof leaf is a 45 deg sector of a circle. The top leading leaf has a radius of 207 ft and weighs 300 tons. Its curved base is about 162 ft long, and the distance from ring girder rail to pivot (measured along the curved axis of the roof arch ribs) is about 250 ft. Leaves vary slightly in size so they can nest together. Each leaf is about 3 ft thick, including roof and ceiling. Structural framing is shown in Figs. 5 and 6, the radial ribs, being 30-in. WF beams. Each rib is composed of a series of straight beam sections mitered and then spliced together by shop butt welds to form straight chords following the compound spherical surface of the dome, the shape approximating the dead-load string-polygon. The butt welds were formed by welding the webs first. The rib portion was then turned 90 deg, and the upper and lower flanges were welded in the flat from one side, using backing strips. Finally, it was turned 180 deg, the backing strip removed and the root passes gouged and rewelded. This welding was performed with semiautomatic submerged-arc equipment.

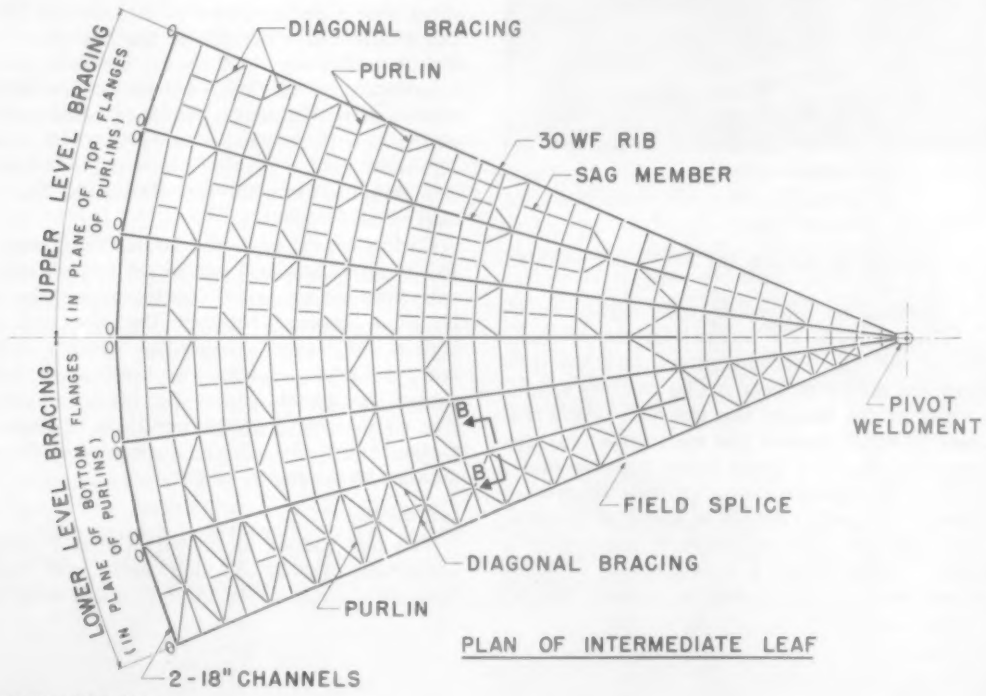


Fig. 5—Roof leaf framing

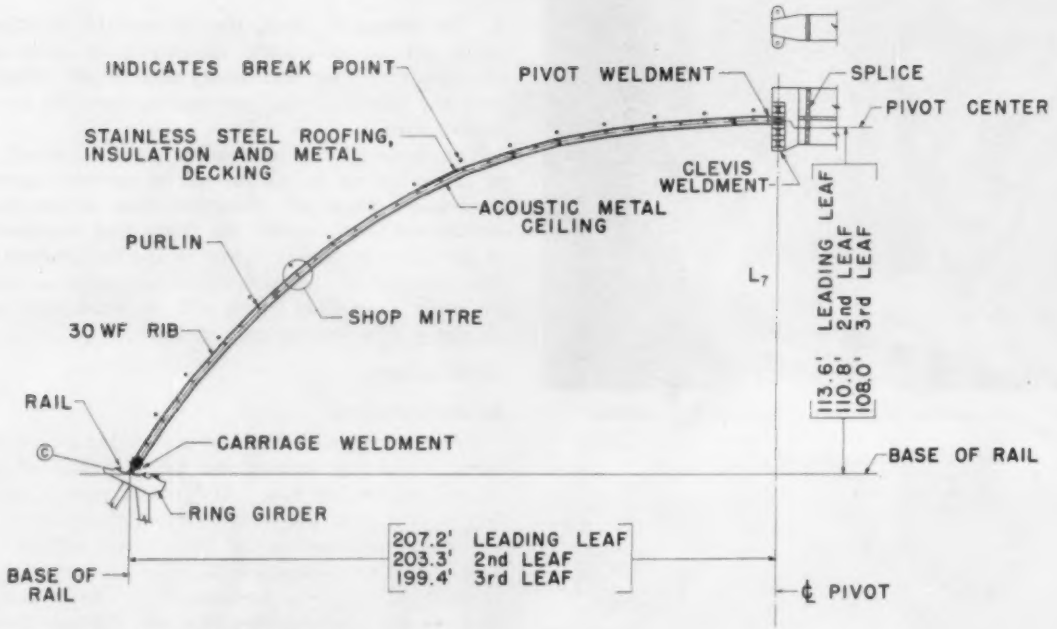


Fig. 6—Structural details of roof leaf framing

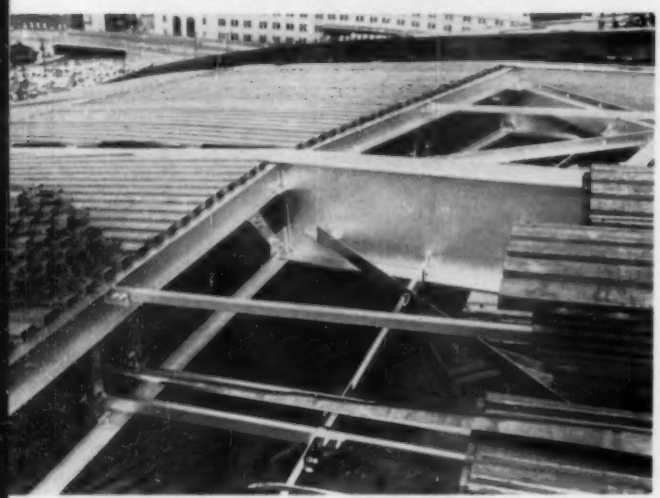


Fig. 7—Leaf roofing during construction

Prior to welding the flanges, the web was preheated in the weld zone.

Field connections are made with high-strength bolts. These splices are located in the straight portions of the ribs between miters, and the ends of beams are milled to bear. The ribs are spaced 27 ft apart at the base of the top leaf. As a leaf decreases in width toward the apex, alternate ribs are discontinued, their loads being transferred by cross framing to adjacent ribs. To keep the over-all thickness of the nested leaves as small as possible, the clear distance between them is reduced to a minimum. Consequently a high accuracy of fabrication and erection is required to prevent binding between leaves. That all the ribs of a leaf must concurrently bear against one common milled surface on the pivot weldment is further reason for accuracy. For these reasons each rib was shop assembled in its entirety, with the milled ends at all field splices tightly drawn up.

The leaf ribs were designed for two conditions of loading: (*a*) for the conventional stresses under dead load and uniform live load of 15 psf over the entire leaf plus a pattern load of 15 psf placed for maximum effect at the design sections, and (*b*) for yield point stresses under dead load plus a pattern load of 50 psf on one half placed for maximum effect plus a uniform load of 20 psf over the other half of the roof. Because of the nonlinear increase in the secondary (deflection) stresses which are augmented by the large transverse horizontal deflection of the cantilever frame at pivot points, the second condition usually controlled. A transverse deflection at the pivots amounting to about 1 ft. is maximum for a 30 psf differential live (snow) load on half the roof.

Purlins consist of 8- and 10-in. WF beams spaced $7^1/_2$ ft apart and end connected for full continuity span between the radial ribs to support the roofing. Diagonal bracing between the ribs and purlins stiffens the leaves against the traction, wind and bumper forces. Purlins and bracing are field connected to gusset plates by high-strength bolts. The shop welding of the hundreds of these gusset plates to the ribs affords a great simplification in details and savings in weight.

Leaf Roofing

The leaf roofing as shown in Fig. 7 consists of Robertson 3-20-Q decking and rigid insulation with an exterior covering of stainless steel of AISI

Fig. 8—A pivot weldment in shop

designation Type 302, Finish 2-D and of 20 and 22 gage. Bolts with rubber and steel washers under their heads clamp down the decking. Circumferential decking joints with oversize holes permit sliding and minimize distortion of the decking from interaction with the deflecting leaf. Also to avoid interaction and to allow for differential expansion and contraction due to temperature, the radial joints in the stainless steel gage metal are perpendicular and covered with battens, as illustrated, and the circumferential joints are flexural lock seams to permit sliding.

At the top 50 ft of each leaf, which is at a flat slope, the joints are made by field seam welding. False welded caps are attached to continue the batten lines for the sake of appearance. The hung ceiling of each leaf, rigidly suspended from the structural framing, is of perforated steel sheet, zinc coated and with a baked enamel finish. Expansion joints are located in the ceiling between ribs.

Pivot Weldments on Leaves

As illustrated in Fig. 8, the converging ribs at the apex of each leaf join into a single pivot weldment which delivers the leaf thrust—a maximum of 335 tons—through the pivot to the cantilever frame. Each of these weldments is made up of a combination of one carbon steel casting and four short lengths of WF beams, all shop welded together and stress relieved. The short beams are butt welded to the casting and form stubs to which the ribs are field bolted. The casting has a 23-in. diam bore to fit a double flanged Lubrite lining. The inside of this lining is machined to fit a stainless steel spherical knuckle over which the leaf can rotate in any direction without end restraint to accommodate relative rotation between a leaf and supporting cantilever frame. The stainless steel knuckle, bored to accommodate a Lubrite bushing, is mounted on a vertical 12-in. diam pin fixed between two of the ears of the multiple clevises at the end of the cantilever frame. Opening and closing movements take place around this pin. Stainless steel and self-lubricating Lubrite bearing surfaces have been used at both the spherical and cylindrical surfaces so as to reduce maintenance, access being difficult.

Wheel Carriages

The wheel carriages at the base of each leaf rib are 27 ft apart for the top leaf, and $26^1/_2$ ft and 26 ft for the two intermediate leaves. All carriages are double-wheeled, except for the end carriages of the intermediate leaves and the trailing end carriages of the top leaves, these being single-wheeled. Each double-wheeled carriage supports the leaf by means of a 7-in. diam forged steel equalizer pin passing through a Lubrite-lined casting bolted to the leaf. Each of the 30-in. diam rim-toughened, wrought-steel, double-flanged wheels is designed for a maximum reaction of 60 tons in the plane of the wheel accompanied by a transverse force of 4 tons delivered against the flange when the roof is closed and has full live load. Under motion, each wheel is designed for a reaction of 35 tons, a transverse 2 ton force on flange and a tractive force of about 13 tons. The wheels, weighing 1500 lb each, rotate on pairs of spherical roller thrust bearings which are mounted on 6-in. diam forged steel shafts fixed to the carriage side plates. The carriages, themselves, are stress-relieved weldments made up of stiffened plates of thicknesses up to $2^1/_4$ in. The weight of each double-wheeled carriage, exclusive of motors and brakes, is four tons.

The 25-hp drive motors and brakes are mounted above the intermediate carriages and are connected to the wheels by means of sprockets and roller chain drives. Only one wheel of each carriage is driven, but both are braked through gear reducers. A self-contained hydraulic buffer is mounted at each edge of each movable leaf, should the leaves hit the fixed bumpers or the cantilever girder at too high a speed in the event of control failure. Under operating conditions, opposing pairs of leaves will operate symmetrically. The control system not only insures this operating condition but controls the differing rates of movement of each of the various pairs of leaves. The controls, the many safety features, and the comprehensive trouble indicator panel result in a highly complicated and unique electrical design.

Rails

The reinforced concrete ring girder serves to support some 3000 linear ft of rail, curved to radii averaging about 200 ft. Each rail is accurately bent about both its axes so that its web lies on a conical surface.

Fig. 9—Field welding of rail connections

Attachment of the rails to the ring girder is made by anchor-bolted base plates spaced at 3 ft 3 in. on centers. Each $1^1/_4$-in. base plate is accurately positioned above four jam nuts, then fastened down by another set of nuts and finally grouted. The curved 175-lb rails are accurately placed and clamped tightly into permanent position by pairs of snug-fitting 1-in. thick wing plates which secure them laterally but permit longitudinal temperature expansion. To permit transverse adjustment in setting rails, the wing plates are furnished loose and are field welded to the base plates—Fig. 9. For this operation some 1500 linear ft of manually applied double-vee $^5/_8$-in. tee weld are required.

The ring girder, itself, has expansion joints, the faces of which—in addition to opening and closing from temperature—move radially and rotate with respect to one another during a passage of load. A special floating rail portion bridges the ring girder joint to allow for these motions.

Closure Devices on Leaves

The weatherproofing of the joints at the bottom and at the radial edges of the roof leaves is complicated by the end rotations and differential deflections between the leaves when they are subjected to nonuniform wind or snow loads. The openings and closings of the joints make weatherproofing a difficult detailing problem and require various closure devices.

The radial closure between the abutting edges of the two leading leaves is accomplished as follows: One leaf has a stainless steel-clad pipe nosing attached to its leading edge. When the roof leaves reach their final position, this nosing cushions itself between two neoprene bulbs attached to the other leaf. Differential vertical deflection between these two particular leaves is prevented by a shear interlock device.

The radial closure at each of the six trailing edges of the two movable leaves is accomplished by a flexible, bulb-shaped neoprene seal suspended from the upper leaf and extending over the full radial length of the joint. Flexible neoprene curtains form a weatherproof connection between the bulb and the upper leaf. When a roof leaf reaches its closed position, a steel cable within the bulb is tensioned by a mechanical linkage, in turn actuated by a tripper plate on the ring girder. The resulting radial component of cable tension pulls the bulb downward, compressing it against a smooth pad on the adjacent leaf below and effecting a waterproof seal. The neoprene curtains have enough slack so that the maximum expected differential deflections between two adjacent leaves will not lift the bulb from the roof surface. When the roof opens, the tension of the cable within the bulb is released, and the bulb is lifted to a retracted position by a spring tensioned suspender cable.

The circumferential closure at the bottom of each leaf is achieved by a neoprene bulb attached to the edge of each leaf. As the roof closes, the bulb moves into a position adjacent to a curved steel curtain plate mounted on the ring girder. Leaf springs clamped to stem of the bulb hold it clear of the plate when the roof is open. As the leaf reaches its closed position, a tripper mechanism tensions a cable within each bulb and compresses the bulb against the curtain plate.

Closures at other points such as the apexes of the roof leaves are made by means of various inter-sliding annular rings, abutting closure plates and neoprene bulbs.

Cantilever Frame

General

The cantilever, which supports the pivot points of the roof leaves, is a structural steel space frame located at the rear outside face of the roof. It is basically an inclined, curved tripod—Fig. 10. The lower leg of the "tripod"—an 8- x $7^1/_2$-ft box girder acting as the compression member—is curved in a series of straight chords between panel points to a shape approximately following that of the roof and encroaching only a minimum amount below the ceiling line. The two upper legs of the "tripod," also chords of a curve, are 3- x $3^1/_2$-ft box-members acting as the tension tie backs. Positioned high above the rear entrance to the auditorium in order to meet the various access and architectural requirements, they terminate in anchorages about 110 ft to the rear of the ring girder. They are held away from the box girder by triangular frames consisting of struts and cross ties. Toward the top of the girder where such triangular frames would be shallow, they are replaced by cross girders as shown in Section D-D. The profile of each tie back is a string polygon so shaped as to place minimum moment in the box girder when the girder receives its maximum compressive thrust. This occurs when the leaves are nested, at which time

they apply a total horizontal load of over 1500 tons to the pivots. The concurrent vertical load is less than 3% of the horizontal.

The triangles formed by the strut and cross tie members are supplemented by, first, a "K" bracing between tie backs and, second, by diagonals between the plane of tie backs and the top of box girder to form a space frame capable of resisting vertical, horizontal and torsional loads. Members other than the tie backs and box girder are 2- x $2^1/_2$-ft box members.

The cantilever frame design utilizes the computed participation of all members, since the box girder is rigidly attached to its abutment, the space frame is indeterminate to the fifth degree.

Interconnecting the space frame members at the panel points presented a serious design problem, since as many as seven space frame box members intersect at one point. Further, few of the member sides lie in common planes, and many of the intersection angles between the members are sharp. Various riveted, bolted, pin and weldment type connections were studied before selecting the shop-welded, field-bolted, "stub-weldment" design which was finally shown on the contract drawings. It consists of a group of intersecting rectangular stubs, each suitably reinforced at its interior with welded diaphragms or plates to permit the transfer of stress from the abutting stubs welded to its exterior surfaces. All stubs are field-spliced to the

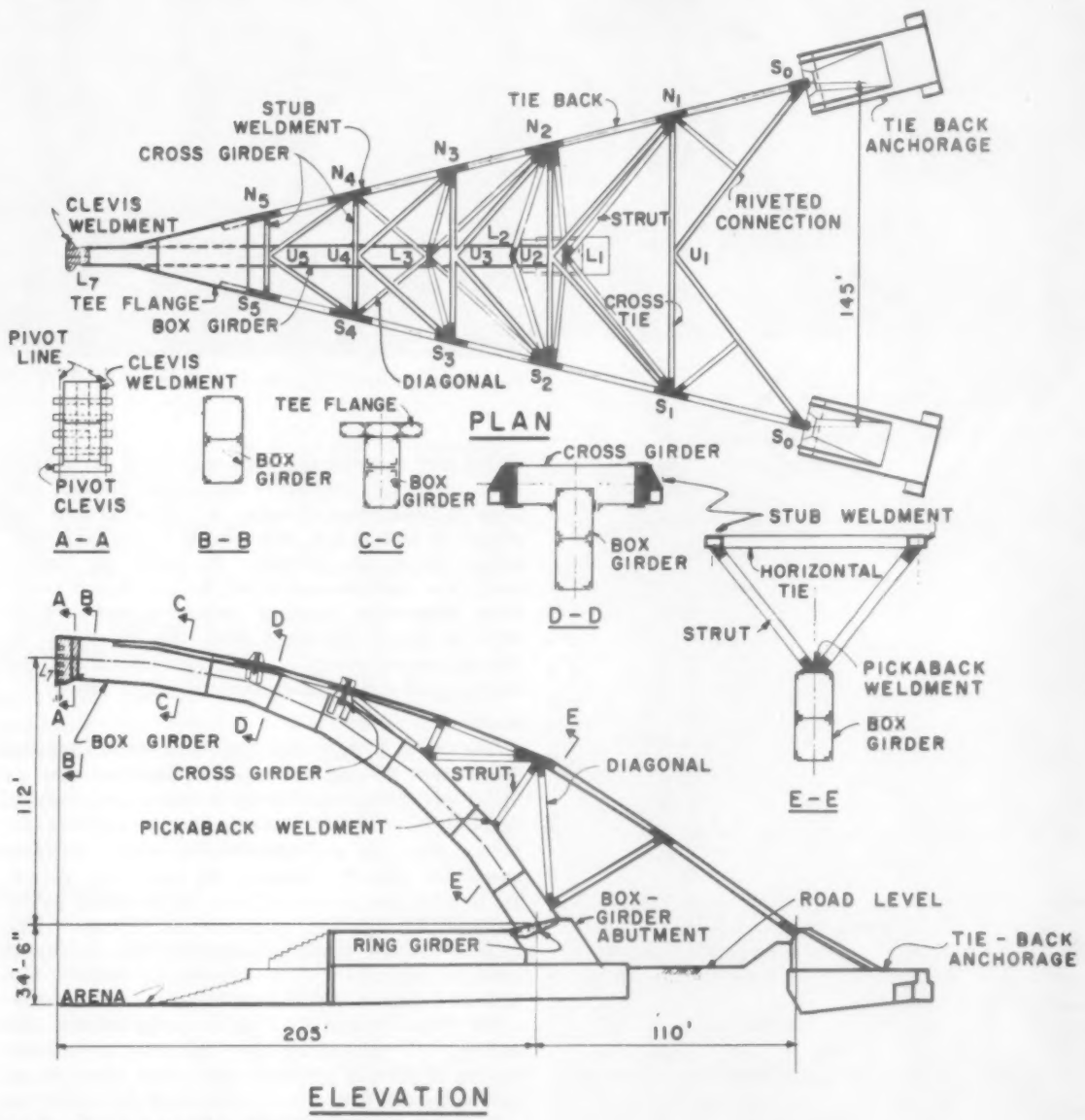


Fig. 10—Plan and elevation of cantilever frame

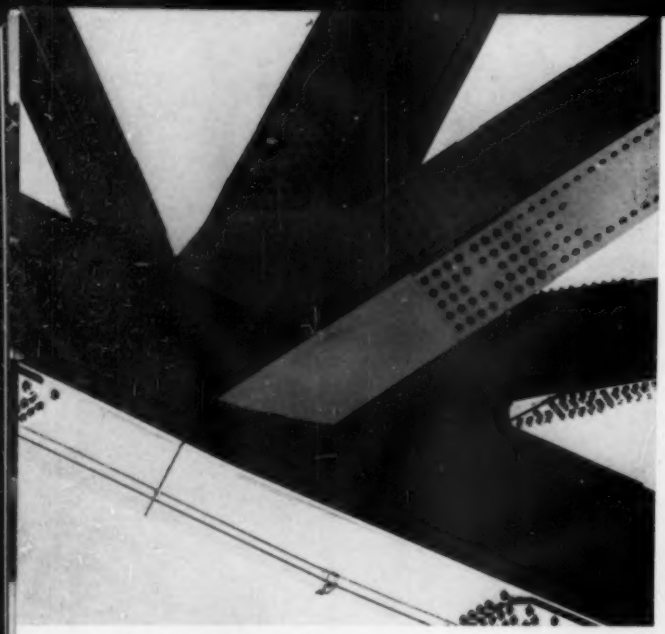


Fig. 11—A stub weldments

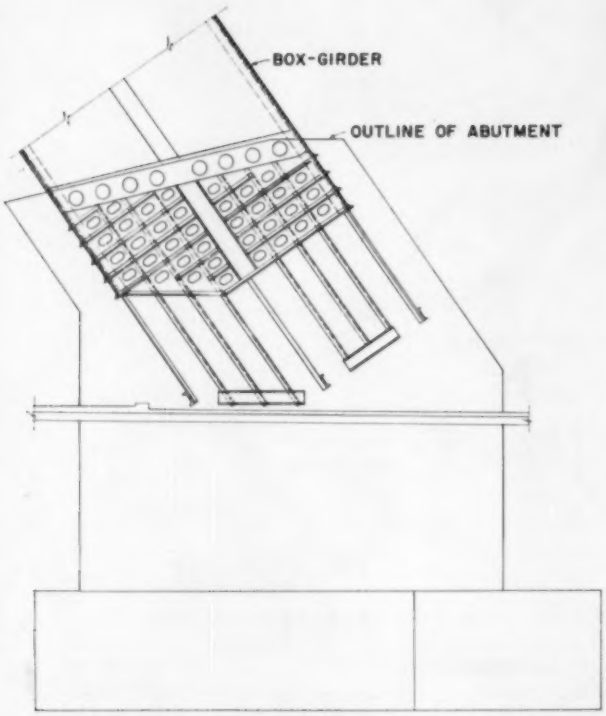


Fig. 12—Detail of embedded base of box girder

space-frame members by high-strength bolts. Although the contract specifications left the contractor free to select any other appropriate manner of connection, he elected to use the stub weldments such as shown in Fig. 11.

The deflections of the loaded cantilever are of particular interest because of the interdependence of leaf and cantilever design. When the leaves nest, the tip of the cantilever moves outward 3 in. and downward 6 in. An unbalanced snow load on the

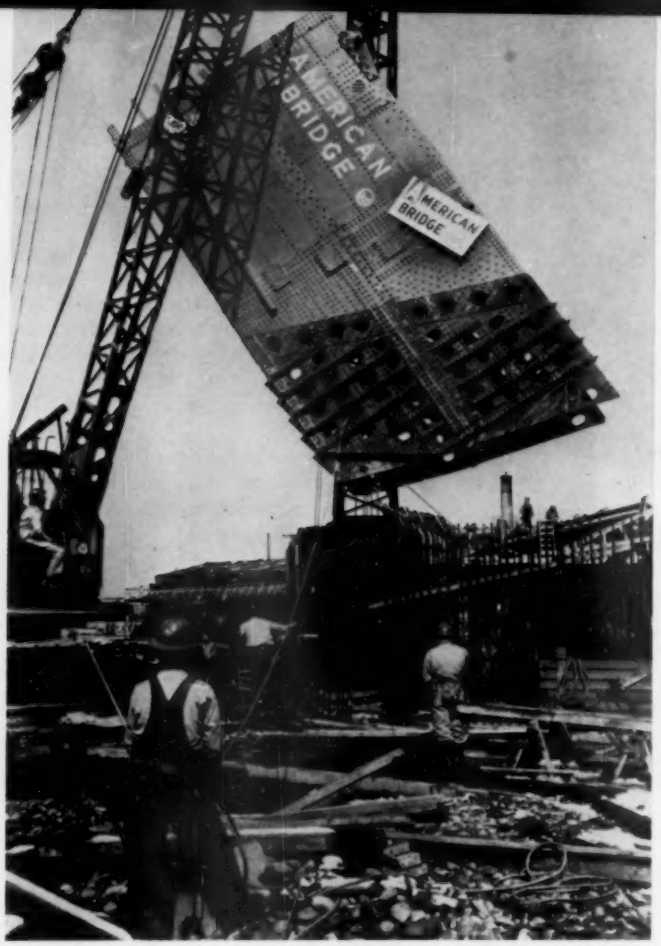


Fig. 13—Box girder being lowered into place

closed roof causes a sideward movement of about a foot. After the cantilever frame was erected, and prior to installation of leaves, a load of 50 tons was placed on its free end, deflecting it $1^3/_8$ in. and verifying the design stiffness. In order to further verify the rigidities calculated for leaves and cantilever interacting together under various loadings such as unbalanced snow load, the leaves will be opened unsymmetrically after completion, and deflection and strain measurements will be made.

Box Girder

The 8- x $17^1/_2$-ft box girder of the cantilever frame is a riveted box member divided into an upper and lower section by a continuous web at mid-height. Its lower section has a stairway for access from the auditorium to a winch platform suspended directly beneath the leaf pivot points. Its interior also provides a path for the many cables required for lighting, operation and control. The base of the box girder is embedded in a reinforced concrete abutment in a manner to transfer the thrust, moment and torsion reactions to the concrete—Figs. 12 and 13. As shown in Section E-E of Fig. 10, a "pickaback" stub weldment is mounted on top of the box girder at each point where struts and diagonals frame in. Its manner of connection will be described later. Near the upper end of the

Fig. 14—Pickaback welding during construction

box girder the struts and cross ties are replaced with cross girders riveted to the box girder. Finally, the tension tie members converge toward the box girder and are connected to it by tee flanges as shown in Section C-C. The front end of the box girder terminates in the clevise weldment described below.

Since the concurrent thrusts of the roof leaves on the box girder vary in direction and sometimes in magnitude, the resultant force of these concurrent leaf thrusts upon the clevise weldment is usually eccentric to the centerline of the box girder. The resultant forces introduced by the "pickaback" stub weldments—Fig. 14—are also often eccentric. Hence, the entire box girder and its clevise weldment —Fig. 15—are designed to withstand the resulting bending and torsional moments.

Clevise Weldment on Box Girder

The clevise weldment at the front of box-girder, indicated in Section A-A of Fig. 10 is 20 ft high, 15 ft wide and 10 ft long. At each of its sides protrude hollow, tapered ears of a 36 x 18 in. rectangular cross section to form the multiple clevises supporting the 12-in. diam pivot pins for the leaves. The pins are held between the clevises by large 4-in. thick collars welded to the ears as shown in Fig. 8. In order to avoid distortion of the machined

Fig. 15—Clevise weldment during construction

Fig. 16—Tie-back anchorage weldment in place after fabrication

forged-steel pivot pins and any misalignment of the pin centers from distortion of the weldment, the weldment was furnace stress relieved prior to attachment of pin collars. To prevent distortion and to partially relieve any residual stress that might build up in the clevise ears as the pin collars were welded, a welding procedure was established using a special nickel-base electrode with a skip sequence. The high ductility of this weld material permitted its peening without building up brittleness in the weld. All weld passes were peened except for the first and last ones. To insure proper amount of peening, pairs of temporary nubs were mounted about 10 in. apart on the main material and as close to the final toe of the weld as possible to form a peening gage. After each peening operation, the distance between nubs was measured to check that the metal remained undistorted.

Pickaback Stub Weldments on Box Girder

As shown in Section E-E of Fig. 10, some space frame web members terminate in "pickaback" stub weldments surmounting the box girder. These weldments are field connected by heavy fillet welds at their base to sole plates on top of the box girder. The sole plates are riveted to the girder, the rivets being countersunk in the vicinity of the weldment base. The weldments were furnace stress relieved after fabrication. After field welding, a procedure similar to that previously described for the clevise weldment was used.

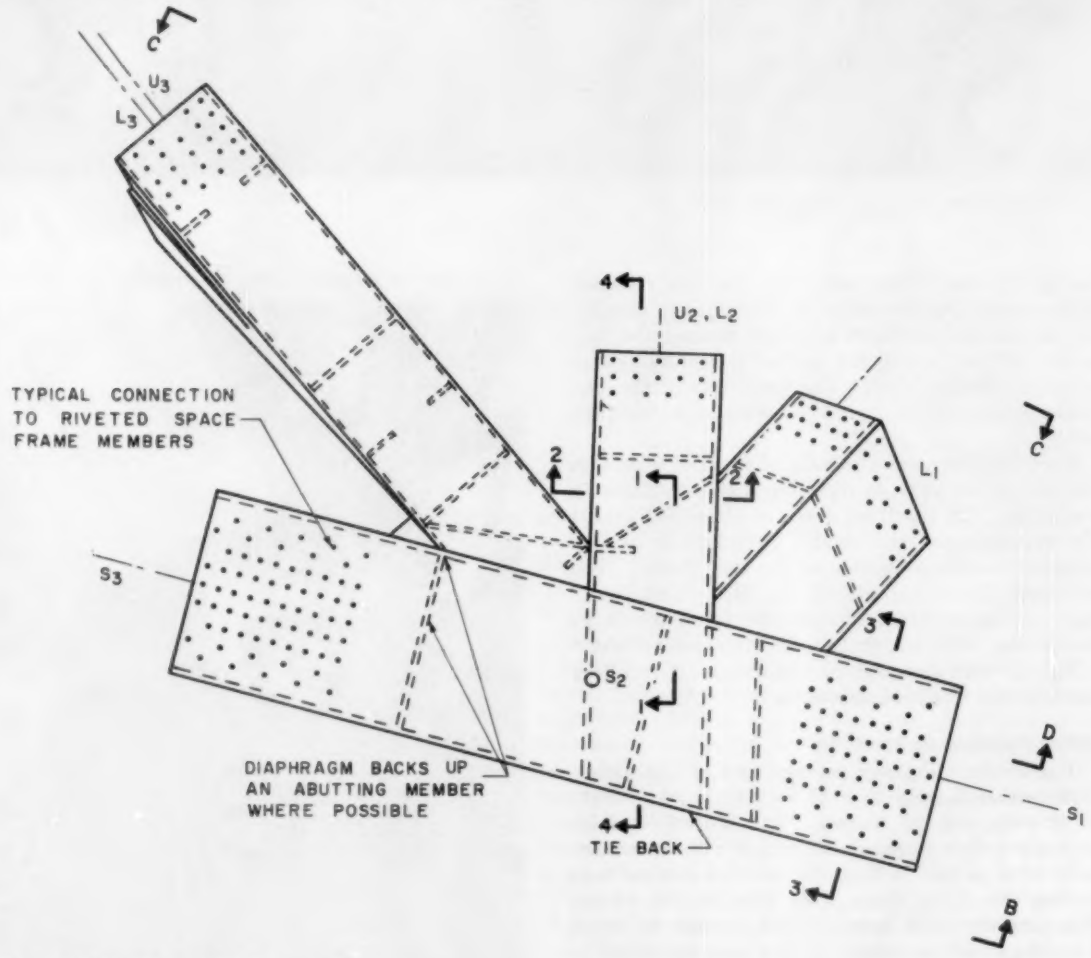


Fig. 17—Stub weldment details—one view

Tie Backs and Tie-back Anchorage Weldments

The two tie backs are each subjected to a maximum force of about 2100 tons when the roof is open and the leaves nested. A stress of comparable magnitude occurs with unbalanced snow load when the roof is closed. These 3- x $3^1/_2$-ft box members are connected to tee flanges flaring out from the front end of the box girder, as shown in Section C-C of Fig. 10. As the tie backs diverge, they are supported, in turn, by cross girders, such as shown in Section D-D and by triangular frames as shown in Section E-E. As indicated in Fig. 16, each tie back terminates at its base in a tie-back anchorage weldment which engages the reinforced concrete tie-back anchorage by means of high-strength anchor bolts, a shear key and dowels. The 3- x $2^1/_2$-in. key is heavily butt welded to the underside of the $2^1/_2$-in. thick base plate of the anchor weldment. It is machined to engage a pair of 2-in. high machined stop bars welded to the upper side of the tie-anchorage shear plate. This shear plate, furnished with shear clips welded to its underside, is embedded in the reinforced concrete anchorage together with the lower 16 ft of the 21 ft long $2^1/_2$-in. diam high-strength anchor bolts. The bolts are coated heavily with bituminous material to prevent bonding to concrete. When the space frame was finally adjusted, the approximate 3-in. space between weldment and shear plate was grouted and the anchor bolts prestressed to 125 tons per bolt, an amount beyond the expected maximum tension. The prestressing minimizes tension stresses in the anchorage, prevents damage to the grouted surface from "working" of the joint under load, and prevents the long anchor bolts from participating in the cantilever frame deflection.

Features of Weldments and Welds for Cantilever Frame

General

In order to illustrate the approach used in the laying out and designing of stub weldments, details of the stub weldment at point S2 are shown in Figs. 17, 18 and 19. Seven space frame members converge at this point. Wherever possible, a diaphragm is so located that its edge backs up an abutting face of a stub as shown in Fig. 17. Where such a diaphragm cannot be introduced, a grid is built up within the stub to back up the abutting face as shown in Section E-E of Fig. 19, such a design taking into account the "hard-points" at the outer nonyielding faces. Where an abutting face meets a surface near a reinforced line in that surface, such as near to the corner of a box or near to a diaphragm edge, then the face is so bent as to meet that corner or edge, and the bend line is properly reinforced with a plate or diaphragm. Some of the areas of the stub elements are made approximately 10% greater than that of the areas of the connecting members because of stress considerations.

All material for the weldments is ASTM A373 steel. Except for the welding of the pin collars to the clevise-weldment and of "pickaback" stub weldments to the box girder as previously described, all welding was performed in the shop prior to stress relieving, either manually with low-hydrogen AWS ASTM A233 grade E7018 electrodes or with semiautomatic submerged-arc welding. Although

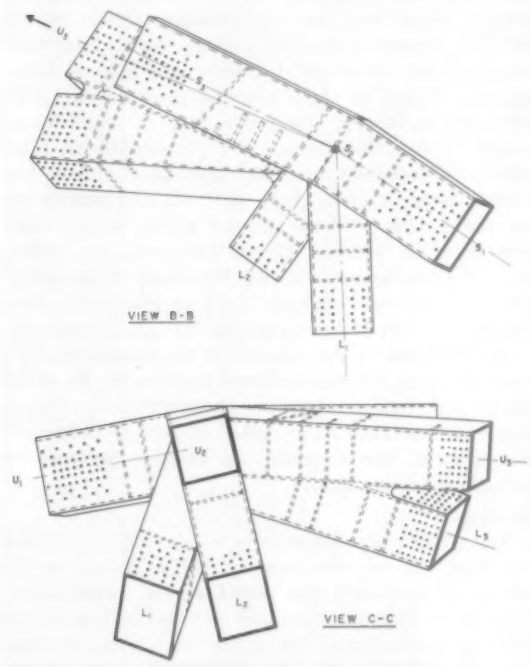


Fig. 18—Stub weldment details—a second view

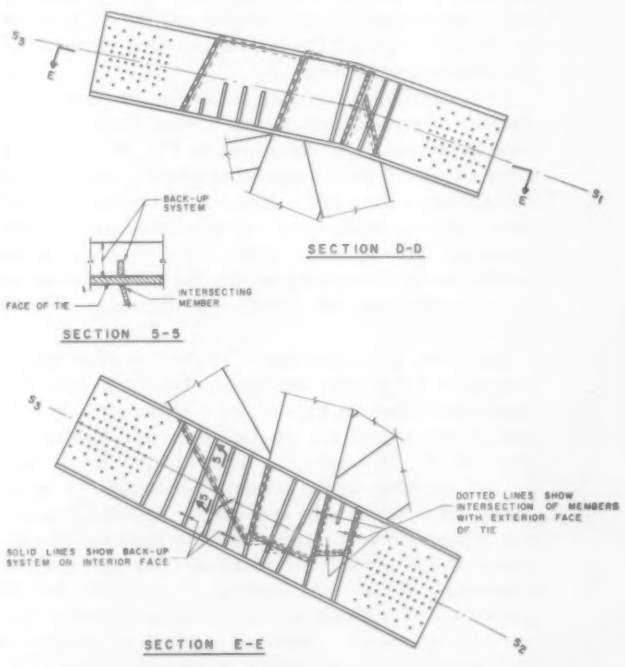

SECTION D-D
BACK-UP SYSTEM
INTERSECTING MEMBER
FACE OF TIE
SECTION 5-5
DOTTED LINES SHOW INTERSECTION OF MEMBERS WITH EXTERIOR FACE OF TIE
SOLID LINES SHOW BACK-UP SYSTEM ON INTERIOR FACE
SECTION E-E

Fig. 19—Stub weldment details—a third view

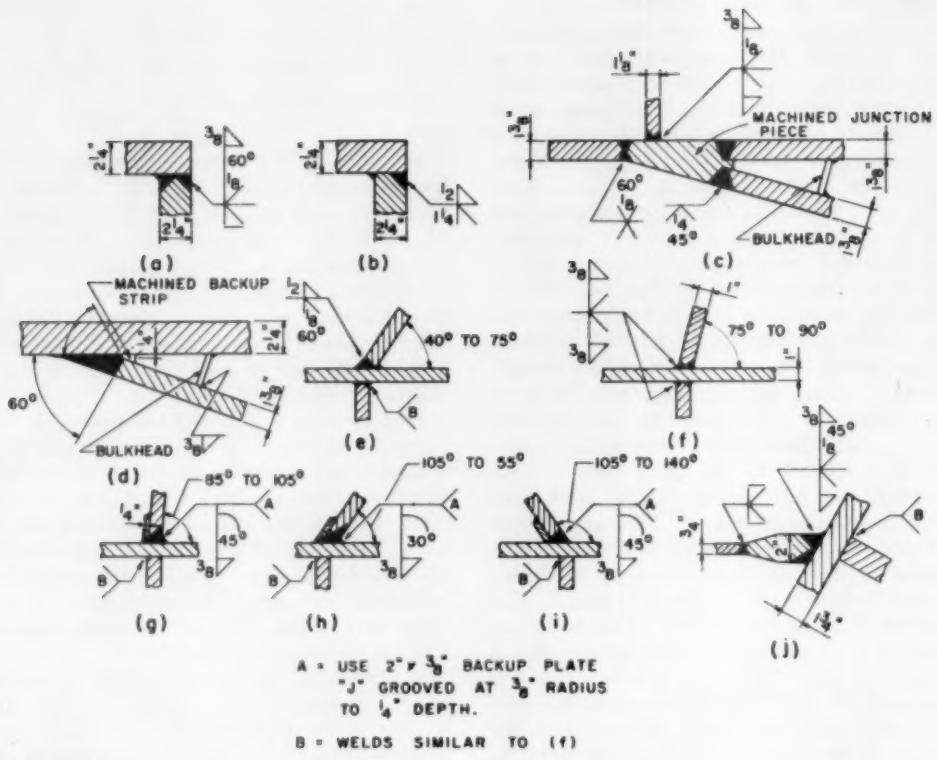


Fig. 20—Typical welds

the dimensions for the groove welds were shaped to meet the requirements of manual welding, the great majority of welds were performed with semiautomatic submerged-arc equipment; only where position or access prevented the submerged-arc's application were manual welds used.

The junction of one stub to another is made by a variety of groove weld types. Some typical welds used in weldment S2 are shown in Fig. 20. A stub's cross-sectional area is somewhat greater than that of the corresponding space frame member in order to meet the requirements of stress combination at the junction with another stub. Where such stress conditions are unusually severe, the stub is increased in thickness near the junction as shown in Fig. 20 (j).

Junctions at highly-acute angles between plates are made by groove welding to machined junction pieces as shown in Fig. 20 (c). Other junctions at less severe angles are welded in manners shown in Fig. 20 (d), (e) and (f). They utilize flat or machined backing strips where necessary. In some cases after the welds are tested, bulkhead plates are welded on so as to seal off the inaccessible portions of the converging surfaces from atmospheric corrosion. This bulkheading is applied to all pockets and corners in the weldments which are difficult to reach. However, as much surface is left accessible for inspection as possible.

The type of connection considered most critical was the double-tee joint which transmitted tension from the edge of one plate transversely through a second plate into the edge of a third. To insure that the second plate had no laminations which would prevent proper transmission of the stress, this plate was carefully examined ultrasonically before fabrication. Welds to each face are groove welds. In addition to having the outer face of weld flared about 1/8 in., these welds are provided with fillet weld reinforcement on each side to eliminate the severe stress raisers that exist at any sharp reentrant corner. Those groove welds, which were accessible for welding at one side only but which require development of full thickness of material, utilize a grooved backing plate to effect this reinforcement such as shown in Fig. 20 (g), (h), and (i).

Accessibility to the interior of the weldments and box members for maintenance is afforded by manholes and ladders located throughout the space frame. Manholes have sealed covers to reduce to a minimum the exposure of interior surfaces to atmospheric corrosion.

Loadings

Each particular point of a weldment is designed for that set of concurrently acting forces in its stubs which yields the worst stress combination. The set of forces is obtained by combination of the loading conditions shown in Fig. 21. The combination of loading causing the maximum stress usually is one of the following three:

1. Dead load with the leaves nested plus live load on the two top leaves.
2. Dead load with leaves nested, plus live load on top leaf.
3. Dead load with roof closed plus snow load on all leaves on one side of the box girder.

In no case does the effect of wind exceed that of live load.

Permissible Unit Stresses

In general, stresses and details of design conform to the requirements of the American Institute of Steel Construction specifications for the design, fabrication and erection of structural steel for buildings.

A maximum value of 20,000 psi was taken as the permissible unit stress for the A373 material used in the weldments, the unit stresses being calculated by application of the octahedral shear stress theory as a criterion of initial yielding. This theory is used in place of other available ones, since the nature of the combination of stresses in the weldments is such that strain energy provides a more reliable criterion of yield strength. Where σ is the unit tensile or compressive stress on a face and T is the unit shear stress on the faces of an element, the combined effective unit stress, σ_e, may be computed as follows:

$$\sigma_e = \sqrt{(\sigma_x)^2 + (\sigma_y)^2 + (\sigma_z)^2 - \sigma_x\sigma_y - \sigma_y\sigma_z - \sigma_x\sigma_z + 3(T_{xy})^2 + 3(T_{yz})^2 + 3(T_{xz})^2}$$

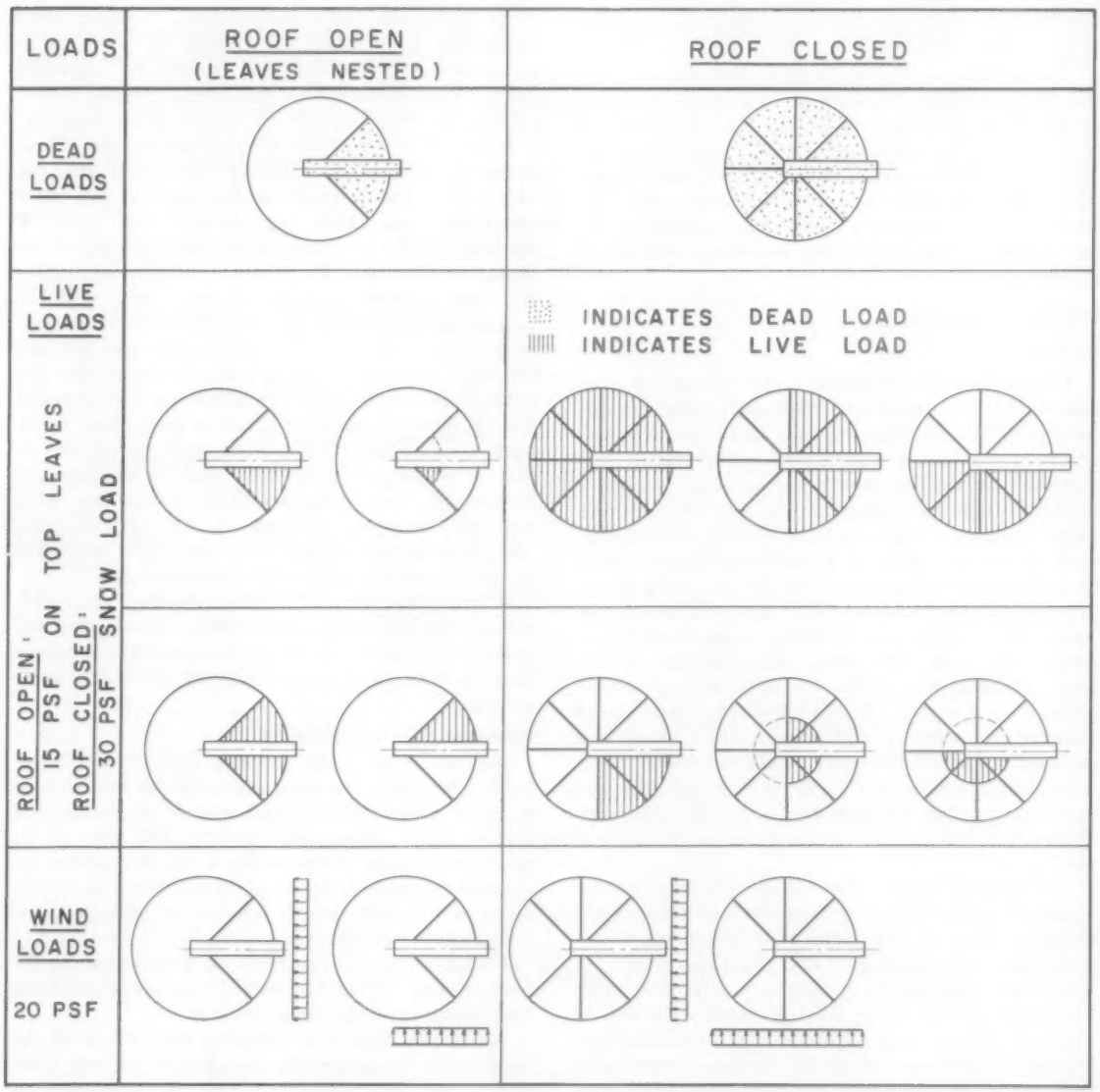


Fig. 21—Loading conditions on roof system.

For the majority of the loading conditions which control the design, the stresses are in two planes only, eliminating five of the nine terms in this formula with a concurrent pair of terms such as $\pm\sigma x$ and $\pm\sigma$, the $-\sigma_x\sigma_y$ term becomes additive. The large contribution of shear to the resultant stress should also be noted in this formula. Had the principal stress theory been used, the calculated critical stresses would have been somewhat smaller.

Stress Analysis

In order to demonstrate the approach used in designing the stub weldments, an analysis for part of the weldment at panel point S2 is shown in Fig. 22. Element "K," one critical point in a section, Section 4-4, is analyzed for the stress calculated from a set of concurrent loads. Referring to Fig. 22, using the area and the moment of inertia of the trial section, the transverse and normal components of the stress in members S_2U_2 and S_2L_2 are applied to the section to obtain the unit shear stress and the varying unit stress diagram of tension and compression. Various points in the trial sections are then analyzed for maximum stress. Such an analysis is outlined here, where the shear and compression contributed by S_2U_2 and S_2L_2 combine with the tension in S_1S_2 to give a combined stress of 20,000 psi, based on the previously described octahedral stress formula.

Welding Procedure

General

The project specifications required that all provisions of the American Welding Society Specifications for Welded Highway and Railway Bridges be observed, including qualification of welding procedures and welders where the welding procedure departed from the standard. It was necessary to make special procedure tests for certain connections, such as the one utilizing a machined junction piece to join intersecting plates—Fig. 20 (c). As a prototype for the qualification test, a test weldment composed of a machined junction piece and short lengths of plate was used. Examination of the test weldment was made by both the ultrasonic method, as a control on this manner of testing, and visually on polished and macroetched transverse sections. The effectiveness of the one-sided butt-joint design shown in Fig. 20 (g), (h) and (j) was evaluated by the fabrication of a qualification procedure weld which was examined in the same manner.

Qualification tests were made for the unconventional groove joints such as the one sided welds shown in Fig. 20 (h), using both the manual and semiautomatic submerged-arc welding processes. Each weld was made in duplicate—one unpreheated, the other preheated to 250° F—and were cut to obtain 0.505-in. diam all-weld-metal specimens and Charpy V-notch specimens for testing of unaffected base metal, of base metal in the heat-affected zone and of weld metal. The Charpy specimens were tested at various levels between room temperature and − 10° F.

A procedure qualification test was made to evaluate the suitability of the use of the special nickel-base electrodes intended for field connections since there is no specification for their use. The purpose of this test was to verify that the strength and ductility were not impaired by the peening operation. At the same time these tests provided an opportunity for qualifying welders and instructing in the proper use of the peening gage. This strain measurement gage was previously described in the description of the clevise weldment. Additional tests were made in accordance with AWS Specifications to prove the shear resistance of these connections.

Stress Relief

All weldments were furnace stress relieved after fabrication and ultrasonic testing of welds were completed. Except for the previously described peened high-nickel welds and for four repair welds, no other welding was performed after stress relieving.

A special test was made to determine the lowest temperature-time combination for A-373 steel at which the yield strength is depressed to not more than 5000 psi. This test showed that 1100° F for 3 hr per in. of thickness satisfied the above requirement. When the weldments were placed in the heat-treating furnace, all legs were suitably braced and propped to prevent distortion. Thermocouples were attached to the thinnest and thickest members to permit heat control and avoid the development of temperature differentials in excess of 150° F between pieces of different thickness; maximum heating and cooling rates were maintained at 200° F per hr unless reduced by those temperature differential requirements. The weldments were removed from the furnace at 600° F. Heating rate, holding time and cooling rate were controlled by use of multipoint control instruments.

After completion of stress relieving, the weldments were retested ultrasonically. Machining was then performed on any surface requiring this operation, such as on large flat bases of pickaback weldments.

Inspection Prior to Fabrication

Inspection prior to welding utilized ultrasonic testing to check the plate material for laminations at those areas where tension was to be transmitted across plate. Areas indicated by this test to be nonhomogeneous were outlined on the plates by colored markers. Unless these defects fell within areas of the plate which were to be scrapped, the entire plate was rejected.

Flame-cut plate edges were inspected visually for laminations. When warranted, dye-penetrant tests were made to verify visual findings.

Assemblies tacked for welding were inspected for compliance in regard to the details of the joint design, over-all dimensions and the cleanliness of the joint faces.

Inspection During Fabrication

Welding currents for both semiautomatic and manual welding were set to the qualification test values, using portable clamp-on type ammeters. Tolerances for all operations involved in the fabrication of these weldments were standardized.

Inspection was concerned with insuring uniform and correct thicknesses of weld passes in manual welding and uniform rates of progression in semiautomatic welding, with avoiding undercutting, with the application of full thickness of backing passes and with attaining the proper contour and specified dimensions of all welds.

All heavy joints were preheated to at least hand warm prior to the deposition of the first root pass. In double-vee joints the root pass was gouged out and inspected visually for complete removal of the unfused metal. When effectiveness of the gouging operation was questioned, dye-penetrant tests were made to ascertain the soundness of the root.

Low-hydrogen electrodes were taken in small quantities from heating ovens where they were kept at 400° F. Similar precautions were taken with flux used in the semiautomatic welding.

Inspection of Completed Weldments

All welds were examined by either radiographic or ultrasonic tests. All the butt-welded 30 in. WF beams of the roof leaf ribs were examined radiographically. The welds of the space frame weldments, most of which are complex, do not lend themselves to radiographic inspection, however, since in most cases the radiographs would have to be interpreted for passing through two or more separate welds and through a material of varying thickness. On the other hand, the ultrasonic method, after appropriate calibration for use in complex welds, permits instant discovery of a local change in character of a weld, indicating a flaw in that area. The areas indicated to be deflective were examined more closely by visual inspection, dye penetrant, magnetic particle or radiography. It is to be noted that in ultrasonic testing, only those discontinuities in the material lying in a plane perpendicular or near perpendicular to the path of the ultrasonic beam produce a signal on the viewing screen, regardless of whether the discontinuity is a crack less than a thousandth of an inch or a small slag inclusion only a few thousandths of an inch thick. Accordingly, the

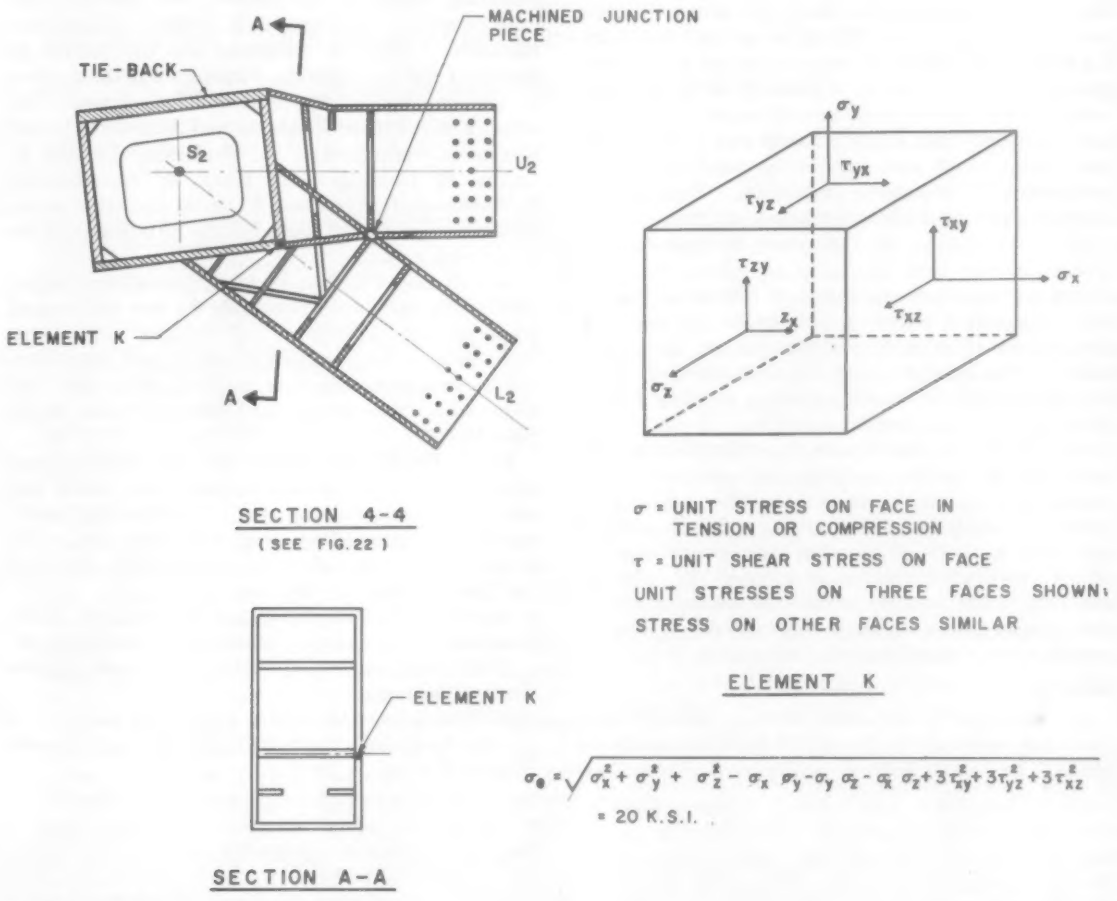


Fig. 22—Stress analysis

effectiveness of the testing method depends primarily on the beam orientation. The frequency of the ultrasonic beam determines its ability to penetrate the desired thickness of material and to overcome the obstacles of large grain size.

During ultrasonic testing, the transducer head is moved in a back and forth sweeping motion. In preparation for testing, the surface on the main materials to be traversed by the head was smoothed by use of a sander and covered by a film of oil. The rate of progression of testing averaged 18 ipm. Isolated defects in the material were identified by small, momentary signals. They were either examined further or were considered as negligible in much the same manner as would have been indications of such defects appearing on radiographs.

In all the welding operations, only four welds had to be removed and rewelded because of cracks occurring in the main material adjacent to the weld. These cracks did not appear to have been caused by any geometric configuration of weldment framing.

The four defects occurred in two completed and inspected weldments which had been moved to an unheated area awaiting transfer to the heat-treating plant. During a storage period of two days there was a sharp temperature drop. In one weldment two cracks—each over 12 in. long—developed in the base metal, and these were attributed to thermal stresses. As disclosed by a macrograph of a transverse section removed from its mid-length, each crack had originated from a flaw consisting of a fold in the base metal which was sufficiently fused to remain undetected by ultrasonic inspection. Propagation of the cracks was of a brittle fracture nature.

The two defects in the other weldment were internal cracks over 12 in. long. These were detected during the reapplication of ultrasonic testing following stress relieving. However, it was not determined whether they developed in the period between the application of the first ultrasonic test and the transfer to the heat-treating plant or during the heat-treating operation.

In repairing the four cracks, the defective area was removed by arc-air gouging and grinding. The completeness of crack removal was checked by dye-penetrant testing. The repair welding utilized the usual methods of interpass temperature control. Block sequence welding was used to prevent cracking. The two stress-relieved weldments were not restress relieved, since the location of the repaired areas was not regarded as critical.

Other Tests

In addition to ultrasonic testing, several other tests not specified by the AWS Specifications were made. One dealt with the calibration of the ultrasonic apparatus for indicating flaws occurring in acute angle, full penetration tee welds.

A test of two 75-ft long rib sections verified that the residual stresses resulting from the welding did not affect the rib geometry under the design loading and that stress relief heat treatment could be omitted for the 30-in. WF arch ribs shop splices.

Acknowledgment

The owner is the Public Auditorium Authority of Pittsburgh and Allegheny County. S. A. Swensrud was Chairman from Oct. 29, 1954 through December 1959, after which William B. McFall was elected chairman. Mr. Edward Fraher is the Executive Director of the Authority. H. R. Helvenston is Resident Engineer and General Superintendent of Construction for the Authority.

The architects of the project are Mitchell and Ritchey, AIA, of Pittsburgh, Pa., with James C. Armstrong acting as project manager during the design phase and Edward R. Gallagher during the construction phase.

The engineering of the Pittsburgh Public Auditorium retractable roof and supporting structure, including structural, mechanical and electrical features, was done by Ammann & Whitney, Consulting Engineers. Boyd G. Anderson was the partner in charge of design. Werner Ammann was the partner in charge during the construction phase. The authors were Project Engineer and Assistant Project Engineer, respectively. A. Anderson, L. Au, F. Chang, H. Dandliker, M. Klein, A. Menanteaux, H. Rothman, H. Samelson, F. Serim and other members of the staff participated in the final design of the retractable roof.

Bela Ronay acted as Welding Consultant during fabrication and was responsible for the testing and inspection procedures of all welding operations. Mr. Helvenston supervised all testing and inspection.

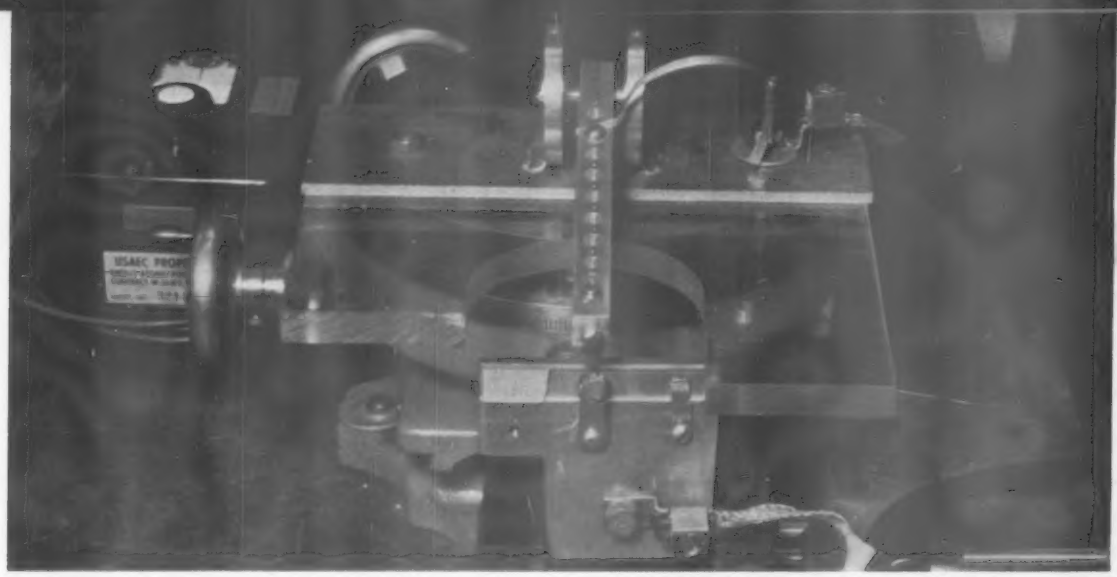
The roof structure was detailed, fabricated and erected by American Bridge Division, United States Steel Corp.

E. C. Ernst, Inc., holds the electrical contract including roof drives and installed the power and control systems for the roof. Leaf rolling equipment was furnished by Heyl and Patterson. The drive, control and indicator systems were furnished by Westinghouse Electric Corp.

Limbach Co. fabricated and installed the stainless steel roofing and the weather seal closure system.

Dick Corp. performed all the reinforced concrete work on the project.

Photographs used in this article are courtesy of U. S. Steel Co., Heyl & Patterson and Lincoln Electric Co.



Mechanical fixture used to autobraze thermoelectric materials

Resistance **Autobrazing** of Wires to Intermetallic Thermoelectric Materials

involves a new process characterized by the self melting of one base metal and wetting of the second base metal to complete a joint

BY W. A. OWCZARSKI

ABSTRACT. A welding process, called resistance autobrazing, has been developed and permits the joining of metallic probes to compound thermoelectric materials. Several of these materials have been successfully equipped with probes. Iron, chromel, alumel and platinum probes, among others, have been joined to PbTe, Bi_2Te_3 and ZnSb. Wires of several diameters and samples of different geometries have been used.

The developed process resembles brazing. However, one of the materials to be joined provides filler metal to the joint. The process uses resistance heating to provide the energy required to melt the "filler metal" and complete the joint.

Introduction

The application of conventional welding and joining processes depends, to a great extent, on the composition and geometry of the parts to be assembled. Some materials possess properties which make them difficult to join by any conventional means. The family of intermetallic compounds of lead, antimony, tellurium and selenium is just such a group of materials. These compounds are of current interest commercially because of their thermoelectric properties. They are very brittle and have very low strengths. In testing and applying the thermoelectric materials, it becomes necessary to attach wires to them. Two methods are conventionally used to connect current-carrying wires to the compounds: soldering and percussive welding. Both methods have certain limitations in their application. This article briefly describes the development of a new technique for attaching wires to these compounds.

The process, called resistance autobrazing, produces a direct bond between the wire and base material which is a result of a solid-liquid reaction. The heating is accomplished by passing current between the parts in a manner similar to resistance welding. The results obtained, using this process with a relatively wide range of materials, have been excellent. The major portion of the work described will be on the joining of chromel and alumel wires to bismuth telluride (Bi_2Te_3), lead telluride (PbTe) and zinc antimonide (ZnSb). In smaller quantities, iron, constantan, platinum and platinum -10% rhodium wires have also been successfully joined to the three above mentioned thermoelectric materials.

Materials

The three thermoelectric materials which were used possess physical and mechanical properties which make them difficult to handle. In addition to low strength and ductility, which are characteristic of these intermetallic compounds, two of the materials are mildly toxic. Tellurium compounds

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Table 1—Some Physical Properties of Thermoelectric Materials Used

Material	PbTe	Bi_2Te_3	ZnSb	Chromel
Melting point, °C	922	573	550	1,450
Resistivity, μΩ/cm	5000	800	2000	30
Tensile strength, psi	1000 (approx.)	...	...	80,000
Other comments	...	Strong tendency toward cleavage	...	...

have toxic effects when ingested into the human system. Inhalation of telluride dust or vapor, which might be generated during the joining process, had to be avoided; this was accomplished by means of proper air exhaust. More elaborate precautions were unnecessary because of the small amounts of material heated by the process.

Table 1 lists some of the known physical and mechanical properties of the three thermoelectric materials used. It also contains some properties of chromel for purposes of comparison. In addition to individual probes of chromel and alumel wires, some thermocouples were made from these wires and subsequently attached.

There are marked differences in the properties of the materials joined. One of the most significant, insofar as the joining process is concerned, is the wide difference in the melting points of the materials.

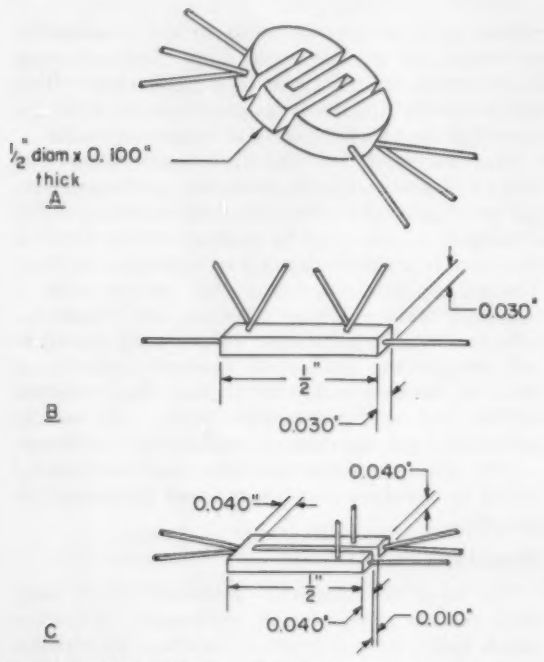


Fig. 1—Sketches of three sample types successfully joined during the development of the joining process. (Note: All were 0.010 in. in diam)

More will be said about this point later.

The mechanical properties of the thermoelectric intermetallic materials are poor. It is possible, for example, to crumble them in one's hands. Shock loading is particularly harmful. A sharp blow of very low energy is sufficient to chip or crack the material. One of the early attempts to attach the fine wires to samples by percussive welding was unsuccessful because the impact of the wire on the surface invariably resulted in cracking or chipping the sample. Even using a drop weight of only a few ounces magnitude falling a distance of less than 1/4 in., was sufficiently severe to cause cracking.

Geometry of Samples

The parts made were to be used for specific measurement of physical properties in a particular experiment. Figure 1 shows three of the geometries which were considered at various times. This illustrates the small size of the samples and points out the criticality of the wire location. At least one sample of each type was made during the process development.

Process Description

Mechanism

The technique developed provides a metallurgical bond between the metallic probes and the thermoelectric materials. This technique is called re-

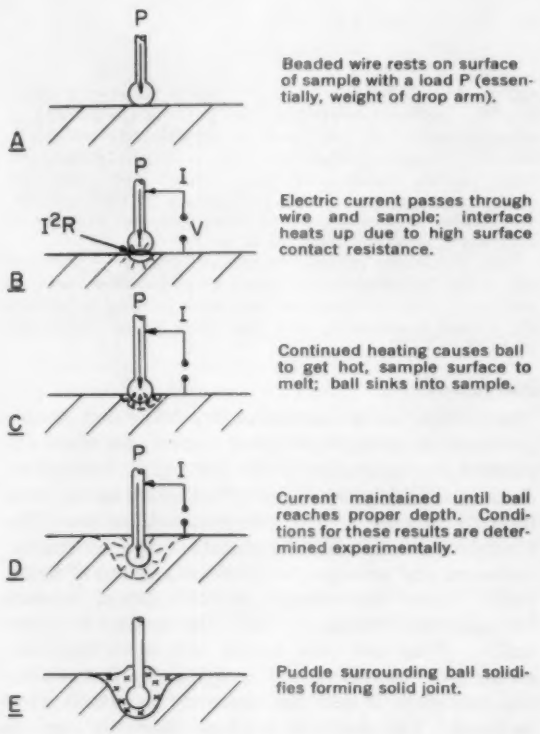

P
A
Beaded wire rests on surface of sample with a load P (essentially, weight of drop arm).
P
I
I²R
V
B
Electric current passes through wire and sample; interface heats up due to high surface contact resistance.
P
I
C
Continued heating causes ball to get hot, sample surface to melt; ball sinks into sample.
P
I
D
Current maintained until ball reaches proper depth. Conditions for these results are determined experimentally.
E
Puddle surrounding ball solidifies forming solid joint.

Fig. 2—Diagrammatic description of the joining phenomenon used in the process

sistance autobrazing. As the name suggests, the process utilizes resistance heating to accomplish a braze joint. The joint is formed by the local melting of one of the base materials to be joined which wets the heated surface of the other component. Upon cooling and resolidification, a braze-type of bond results. Figure 2 shows a step-by-step description of the phenomena believed to occur during the joining process. This illustration shows a beaded wire head and flat surfaced thermoelectric specimen. These are representative of the geometries used. More is said concerning the beading of the wire in subsequent paragraphs.

The apparatus used to effect this joint is shown schematically in Fig. 3. A lightweight drop arm was used to provide the force needed to push the wire bead into the pool. A photograph of this mechanism assembly is shown in the lead photograph. Energy was provided by a standard resistance-welding power supply, which included a synchronous sequence timer and electronic contactors. Other supplementary equipment included a memory-type storage oscilloscope, which was used to monitor current wave form, and a bridge type milli-ohmeter which was used to measure contact resistance, both before and after joining.

Prior to joining, some preparation was necessary to properly condition the materials to be joined. The probes and thermocouples were beaded by melting with a carbon arc in an argon atmosphere. Following this beading operation, the heated ends were cleaned in diluted acid to remove any oxides which may have been formed. Thermoelectric samples were cut by means of abrasive cutting and were rinsed in alcohol afterwards to remove any residue from the processing. Abrasive cutting was used because the sample size and ductility did not permit use of conventional machining. A dental abrasive drill was the tool used for cutting the slots in the samples.

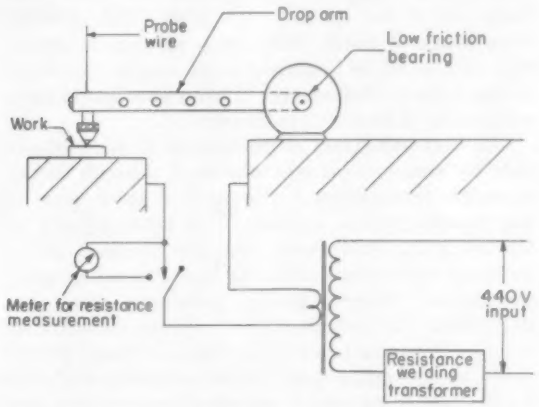


Fig. 3—Diagrammatic sketch of equipment used to make probe connections to thermoelectric materials

Results

Several techniques were employed to evaluate the completed joints. The first of these was a visual examination to see if the ball (wire bead) had buried itself to a proper depth in the sample. Figure 4 illustrates the appearance of a probe buried in a PbTe specimen. This feature provided a limited

Fig. 4—Surface appearance of sample embedded in surface of joint

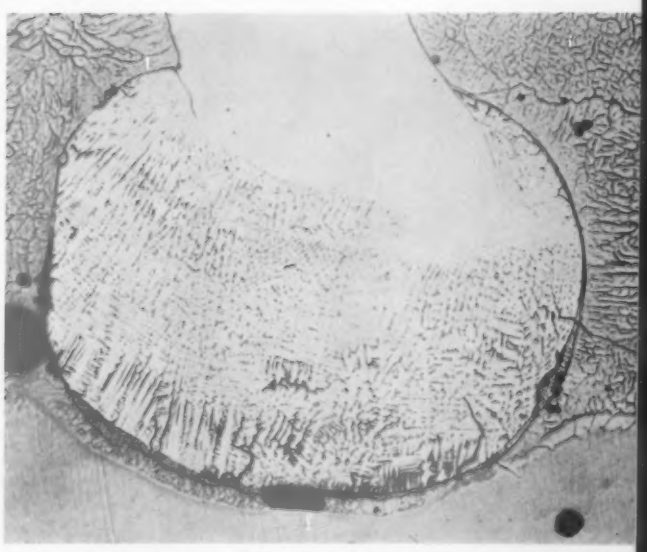


Fig. 5—Chromel probe joined to PbTe. Alloy zone visible along lower edge of probe bead

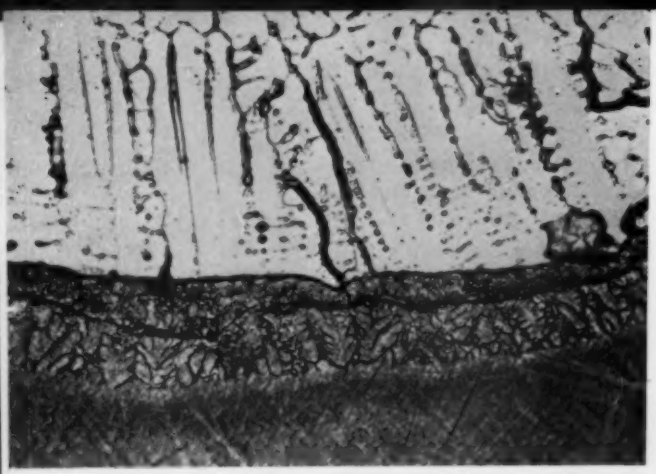


Fig. 6—Alloy zone between chromel probe and PbTe

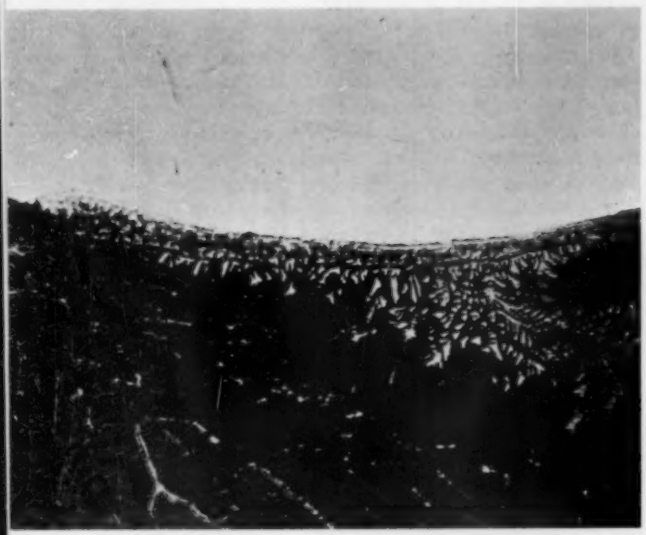


Fig. 7—Alloy layer between chromel probe and ZnSb

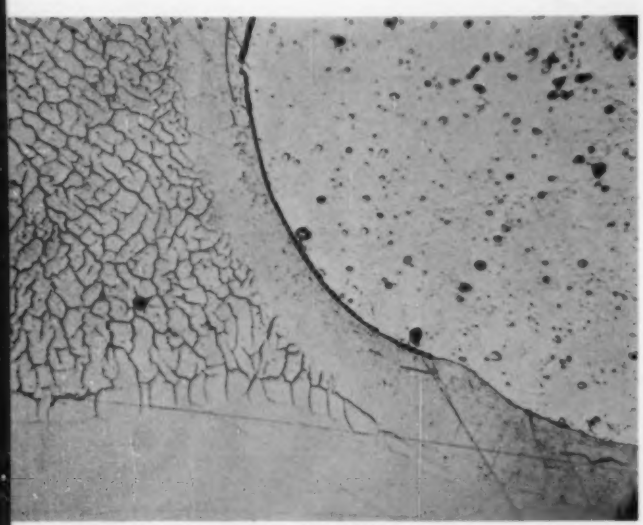


Fig. 8—Alloy layer between chromel-alumel thermocouple and Bi_2Te_3

means of quality control and was one of the reasons why the wires were beaded.

Some indication of joint strength could be determined by pulling on the wires. Normally the wires on poorly-joined samples would pop right out of the socket, whereas adequate joints would offer considerable (qualitative) resistance before finally pulling out. While the test was not employed on used samples, it served to indicate the strength of the joints obtainable when evaluating development pieces.

Electrical resistance measurements were also indicative of the quality of a joint. When bonds were properly made, resistances of approximately 0.05 ohm could be measured quite simply by using a bridge type milli-ohmeter. Poor joints would have resistances of about 0.2 to 0.5 ohm.

The best indication of the quality of joint attainable by this process was observed through metallographic examination. Figures 5–8 show some of the metallographic results. The heterogeneity of the resultant structures and the unusual alloys obtained added some difficulty to the metallographic evaluation. The following technique was used to obtain the metallographic results shown. All samples were cold mounted in resin and rough ground down to 600 grit paper. Final polishing was done by first polishing with 3 micron diamond paste on a cotton wheel followed by an automatic vibratory polishing machine which used 0.1 micron alumina on a gamal cloth. Etching was accomplished using a 10% HF, 45% HNO_3, 45% H_2O mixture for varying times suited to the various materials. The metallographic results showed very definite alloying effects. Figures 6 and 7 show the reaction zone between PbTe and chromel at ×250 and at ×1000. Figures 7 and 8 show the ZnSb-chromel and Bi_2Te_3-chromel-alumel zones respectively at ×1000 and ×500.

Discussion

Resistance autobrazing differs from conventional resistance welding or brazing. Reference to Fig. 9 best illustrates the basic differences in the processes. In resistance welding, both base metals are melted forming a nugget of weld metal which is a mixture of the two. With normal brazing or soldering, a third (filler) material is added which melts and on wetting forms the joint between two base metals. With resistance autobrazing, one of the base metals melts locally on heating and wets the second base metal to complete a joint. This self-melting characteristic is the distinguishing feature of resistance autobrazing.

This feature of the process imposes some requirements on the materials to be used in the joints. The melting points of the materials must be considerably different. In the case of the probe to thermoelectric joints, the thermoelectric materials have melting points which range as much as 850° C below those of the nickel-base probe materials. The melting temperature difference should however, not be too great. If the high melting point material

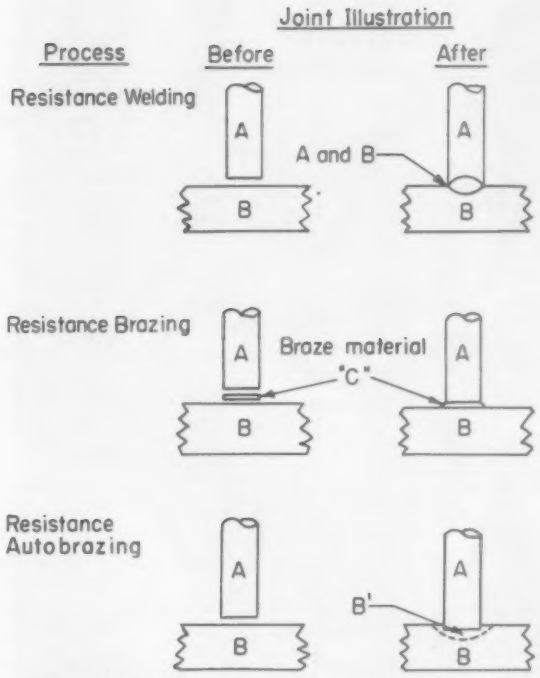


Fig. 9—Schematic comparison of the resistance welding, resistance brazing and resistance autobrazing processes

is not heated to a high enough temperature, solid state diffusion, one of the controlling factors of the rate of solution, will be relatively slow and the wetting either will be retarded or may not even occur. This was evident in some of the samples which were made for this experiment. The joints made between the chromel-alumel probes and PbTe were more easily obtained as the melting point of PbTe is but 500° C lower than that of the chromel-alumel probes. The melting point of PbTe (960° C) is approximately 0.7 Tm (the melting point of the probes) and this is in the range of rapid solid state diffusion. The joints to Bi_2Te_3 and ZnSb were somewhat more difficult to obtain, and one of the factors which contributed to this difficulty was probably the very low melting temperature of these materials. However, by proper process control, these problems were overcome with relative ease.

The metallographic studies showed that some reaction did take place between the probe and each thermoelectric material. The nature of the reactions for each of the systems is not known. A brief survey was made in an attempt to study what phase equilibria exist for the systems under consideration. However, not enough data could be found for the metal-intermetallic compound systems which are involved.

The process parameters proved to be significant factors in the use of this joining technique. The factors which were found to have significant influence on the process were open circuit voltage of the welding transformer, weld current duration and gas shielding. Inert-gas shielding was found to help considerably in preventing oxidation in the vicinity of the joint during liquefaction. Oxide formation interfered with the wetting process to a great degree and the use of argon, flowing over the pool, eliminated this problem. Probes, which were not properly wet, formed "ball and socket" joints and could be turned in the socket.

Surface effects created a number of inconsistencies in the joining process. Cleaning the surfaces was important to help maintain reproducibility, but certain effects which could not be attributed to cleaning procedures were encountered. One of these was thought to be a Beilby layer of disturbed metal caused by sample preparation techniques. The influence of these surface effects was quite formidable when using a welding transformer of low open circuit secondary characteristic. When using a transformer which had a high voltage-low current characteristic, most of the problems of surface contact disappeared. The high voltage evidently breaks down the high resistance of any disturbed layers which are formed in the surface of the semiconductor materials.

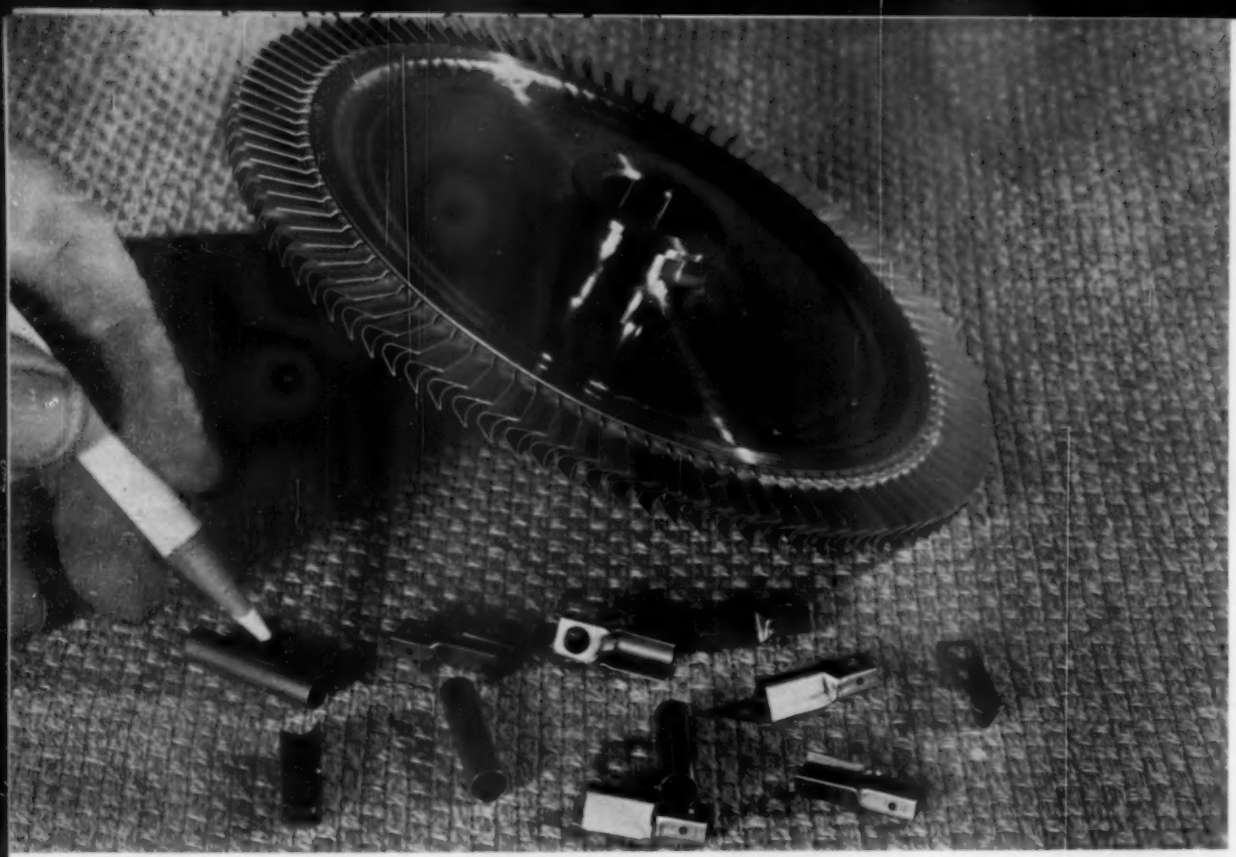
The current duration used in making the samples, of necessity, should be relatively long. Durations of 1 sec or more were preferred to normal resistance weld times which are of the order of $^1/_{10}$ to $^1/_5$ sec. The reason for this was to minimize stresses associated with thermal gradients. Long current durations establish much shallower thermal gradients and, hence, lower internal stresses develop. The inherently low ductility of the thermoelectric materials requires that this precaution be observed. When short heat cycles were employed in attempting to join the probes, a large percentage of samples cracked in the heat-affected zone. This was thought to be attributable to a thermal shock effect.

Conclusion

Successful joints can consistently be made between chromel and alumel probes and Bi_2Te_3, PbTe and ZnSb thermoelectric materials by a process called autobrazing. Resistance autobrazing utilizes resistance heating to obtain a braze-type joint between the materials involved. The process need not be limited to the already mentioned material combinations, but would be limited to those combinations which can use the particular heating and geometric characteristics discussed here.

Acknowledgments

The author wishes to acknowledge the active interest and valuable assistance of Dr. R. T. Frost and Dr. M. Balicki, of Advanced Development Activity, KAPL, under whose sponsorship this program was executed. The author also wishes to acknowledge the valuable advice of J. Bland, Welding Development, and the assistance of R. E. Beach, who performed much of the experimental work. The permission of the Atomic Energy Commission and of the General Electric Co. to publish this work also is gratefully acknowledged.



Finished turbine wheel and bucket components

A Welded Tubular-Bucketed **Turbine Wheel**

improves the performance of airborne accessories and offers reductions in weight and cost

BY E. J. CLARK

SYNOPSIS. Many types of aircraft and missile accessories operate effectively on the turbine principle. They are used in various applications such as for the starting of engines, for furnishing electrical and hydraulic power, for pumping fuel and oxidizers in rocket engines and for the supercharging of piston engine intake systems. The turbine environments include high-temperature compressed air, solid propellent fuels, fuel-air combustion gases and steam resulting from chemical decomposition systems.

Successful performance is closely associated with materials selection, design configurations and fabricating practice. Early turbines employed dovetailing as a method of bucket attachment, but later designs have proven the effectiveness of a less costly welded construction.[1]

The advantage of weight saving is obvious to both the expert and layman. In certain applications of rotating equipment, *reduced inertia* is also very important in that reductions here often permit simpler control equipment and the meeting of closer operating tolerances.

This paper discusses a new concept in turbine wheel design which incorporates buckets formed from 0.010 in. thin-wall tubing which are welded to the wheel using the tungsten arc process. This design permits reduced over-all weight and, since most of this occurs near the wheel periphery, there is also a significant reduction in inertia. This results in faster response which may permit a simpler and lower-cost control system.

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Paper presented at AWS 42nd Annual Meeting in New York, N. Y., Apr. 17–21, 1961.

Introduction

For several years within the Aircraft Accessory Turbine Department at General Electric, attention has been focused upon the potential advantages of lightweight turbine wheels. Some of the early design concepts, especially where cost was critical, were based upon the use of sheet metal parts which were resolved in wheels with buckets of simple configuration. These were often rather limited in operating speed, and the aerodynamic efficiency in most cases was of a low order.

Later development greatly advanced the state of the art in the making of turbine wheels with light-

weight buckets. Methods were developed for making high-strength thin-wall sheet metal buckets (from cylindrical tubing) with high aerodynamic efficiency, and several novel methods of attachment were conceived.

Early wheels employed heat-treated martensitic stainless materials, and the buckets were attached by mechanical methods or by high-temperature brazing. In most wheels, the joints included only partial cross sections of the buckets, but the most effective results were obtained where full box-based buckets such as shown in Fig. 1 were attached to the wheel by brazing. This latter configuration permits taking full advantage of the strength of the complete tube section.

This development demonstrated the potential possibilities of tubular-bucketed wheels. Although considerable test information was accumulated, however, no production applications were made. This was due in part to difficulties in the processing and evaluation of brazed joints for this highly-stressed rotating component.

In early 1958, the advantages of applying tubular-bucketed turbine wheels to a two-stage afterburner fuel pump under development for the General Electric J-93 (Mach 3) aircraft engine became apparent. Weight and cost savings were very significant with the result that development was undertaken on a *welded* design which would permit very high joint efficiency and reliability. This required the selection of suitable materials and heat treatments, and the development of joint configurations and welding procedures, to meet the service requirements of this highly-stressed rotating component. Valuable assistance was rendered by many in the field of general design, stress calculations, metal forming, machining and testing.

Materials

The wheels are driven by compressed air (from engine compressor "bleed-off") which attains a temperature somewhat in excess of 1200° F. Because of space limitations as well as weight-saving requirements and high operating speeds, it was necessary to design for a very high stress level. Among the desirable material characteristics were:

1. Good oxidation resistance
2. High yield strength
3. Good stress-rupture performance
4. Good weldability
5. Relatively low strategic alloy content
6. Relatively low cost

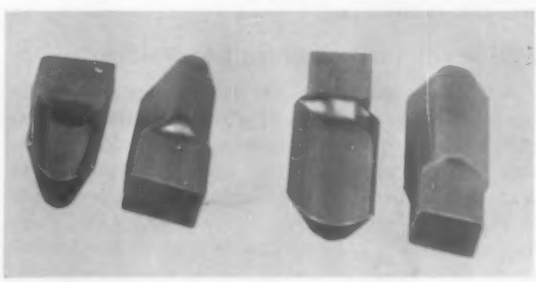


Fig. 1—Typical tubular buckets with box-type bases

Table 1—Chemical Composition of Wheel Components

Element	Percent
Carbon	0.08, max
Manganese	1.0, max
Silicon	0.50, max
Sulfur	0.01, max
Chromium	14.0–17.0
Nickel (+ Co)	70.0, min
Columbium (+ Ta)	0.7–1.2
Titanium	2.25–2.75
Aluminum	0.40–1.0
Iron	5.0–9.0
Copper	0.50, max

These requirements were met for all wheel components by an age-hardenable nickel alloy conforming to the chemistry shown in Table 1. This material has been used exclusively throughout the development for all components of the turbine wheel.

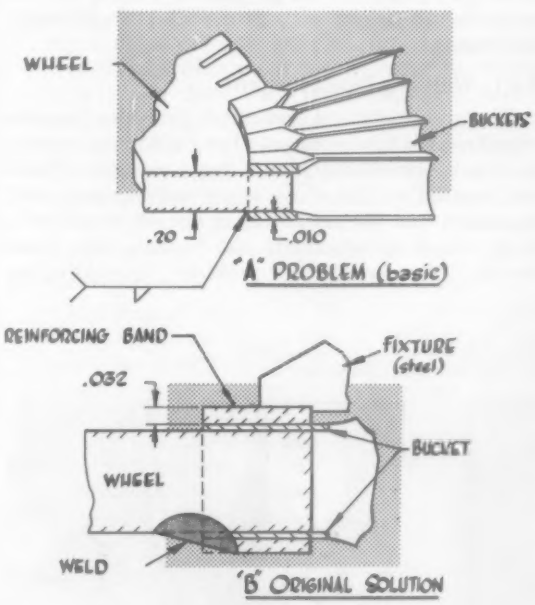


Fig. 2—Joint configurations

The basic wheel forging is supplied in the stress-equalized condition (AMS 5667), and the other parts (buckets and bands) are welded in the solutioned condition. The buckets are made from 0.010-in. wall seamless tubing (AMS 5582), and the reinforcing bands are 0.032-in. thick, conforming at AMS 5542. After final aging the parts attain a tensile strength of 155,000 psi (min) and a yield strength

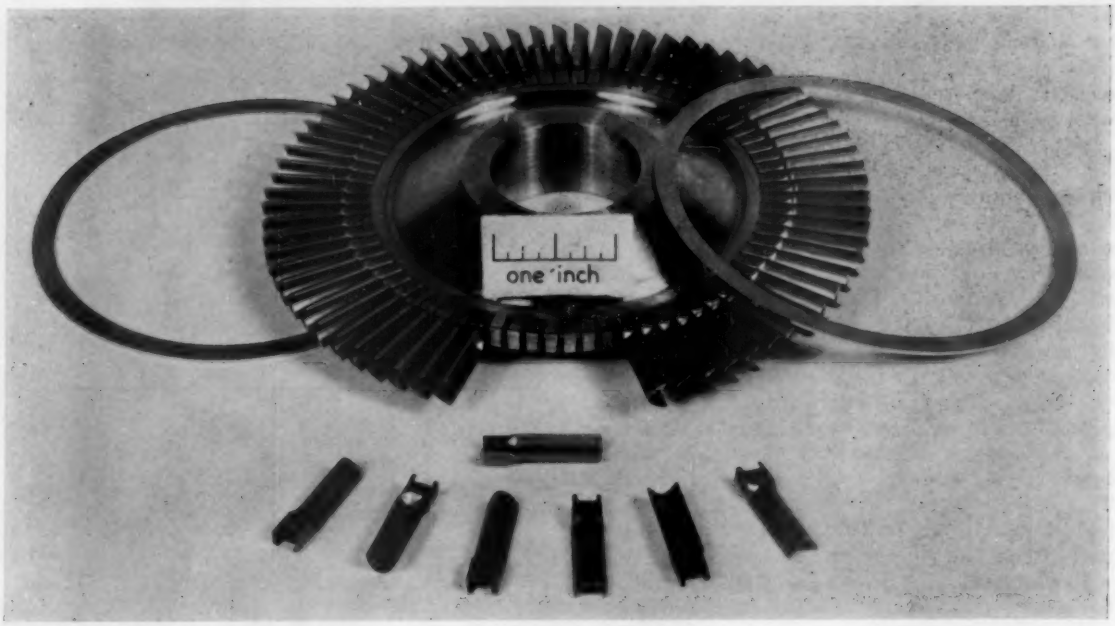


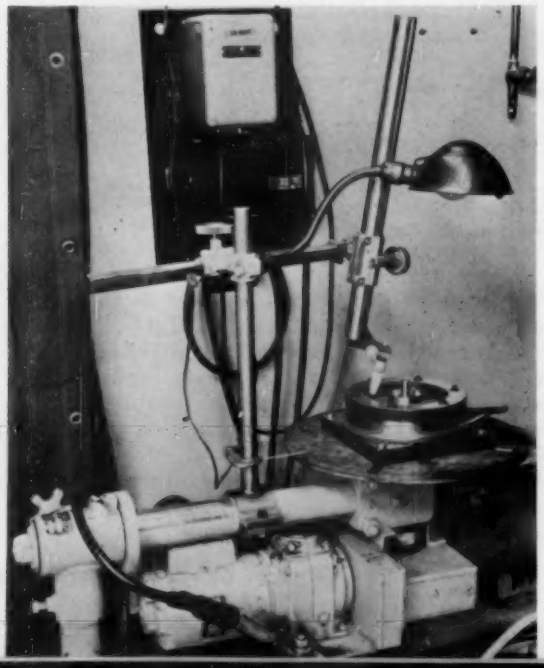
Fig. 3—Components for a welded dynamometer wheel

of 100,000 psi. The design permits welding by the tungsten arc process without the need of additional filler metal.

Early Welding Development

Design calculations indicated that the buckets would require full rectangular box-type bases in order to meet operational stress requirements. These can best be welded when in a closely packed configuration and by employing a slotted wheel with teeth which accommodate the buckets to a close fit-up. This presented a problem for welding as shown in Fig. 2A. Exploratory work proved the inability of consistently welding 0.010-in. thick buckets to a wheel with a thickness in the order of 0.2-in., and the problem was partially solved by employing 0.032-in. thick reinforcing bands as shown in Fig. 2B.

Fig. 4—Starting panel and fixtured turbine wheel on positioner



Facsimile assemblies were welded using a steel fixture, which established the location and contact of the parts and acted as a mild heat sink. The reinforcing band maintained bucket-to-wheel contact and supplied filler material to give the weld shown. Welding was performed in the flat position, semiautomatically in two operations by the tungsten arc process. The welding torch was mounted stationary while a rotary positioner moved the work to give a welding speed of approximately 7 ipm.

Considerable success was realized with this original design. During the development program, two turbine wheels were fabricated for another product. Figure 3 shows the wheel components, which include tubular buckets quite similar to those used for the basic development. These wheels met "overspeed" test conditions and performed satisfactorily for the intended application.

Equipment for Positioning and Welding

All welding developments were conducted on the positioner shown in Fig. 4, which also shows a fixtured turbine wheel and the adjustable welding torch set-up. The panel on the wall accomplishes an automatic starting (and stopping) of the positioner as explained hereinafter. Figure 5 shows the welding unit which incorporates a 6-station sequence timer to permit the use of the automatic schedule further described.

Fig. 5—Welder with 6-station sequence panel and inert gas cylinders

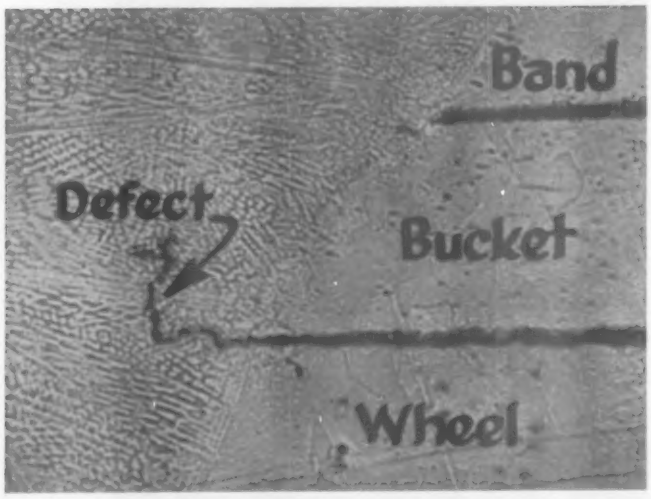
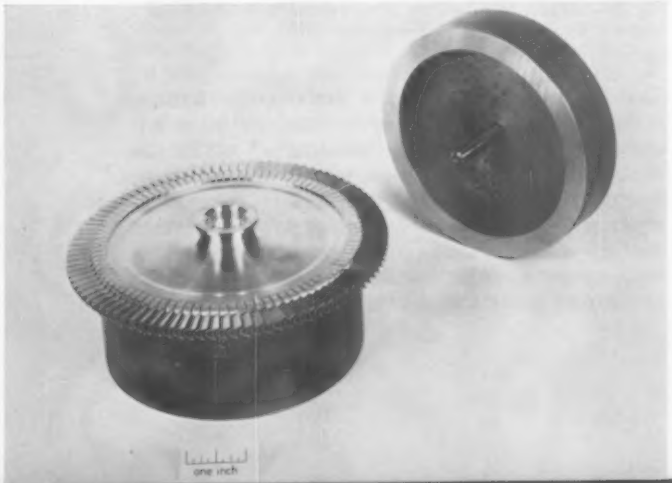


Fig. 6—Partial joint section showing weld defect—X 125

Fig. 7—Setting blocks for improving bucket contact



After set-up, the automatic processing cycle is initiated by the striking of the welding arc (after gas purge) manually by using a piece of tungsten. The flow of welding current energizes the starting panel which, after a predetermined short-time delay, starts the rotation of the positioner. The welding unit is set to give a short time, higher than normal, welding current (to establish weld penetration) which automatically changes into the normal welding current. After 360 deg of rotation, plus approximately 3 sec of weld overlap, the machine automatically tapers off the current to give a crater fill and extinguishes the arc. The determination of the amount of overlap is accomplished by adjusting the weld timer dial in relation to the positioner speed during a "dry run."

Later Welding Developments

As the work progressed, critical areas in design and fixturing were recognized and modifications in configuration and tooling were made in order to produce welds of the highest quality and consistency.

Critical Areas in Design and Fixturing

Early in the development, cross-sectional examinations of joints showed tendencies for small weld cracks which originated at the separation of bucket and wheel, or bucket and reinforcing band. In some cases these turned from a radial to an axial direction as shown in Fig. 6. No appreciable amount of this type of defect could be tolerated, since a very short crack could become a large percentage of bucket thickness. Because of this condition, which was also accompanied by some undesirable weld porosity, an intensive program was conducted for corrective action. The work performed in areas (1) to (5) below was significant in the final correction and control of quality.

Specific Areas

1. *Fit-up of Parts.* At the outset of the project it was recognized that a close fit-up between bucket and wheel must be maintained, not only for welding reasons, but to control uniform bucket pitch and runout. This resulted in establishing a total tolerance of only 0.0035-in. between wheel thickness and the inside of the bucket box. When the aforementioned difficulty appeared, steps were taken to design and build special hardened die steel setting blocks—Fig. 7—so that a concentrated force could be applied to the bucket bases after assembly to the wheel and before welding. This operation performed in a hydraulic press has been used ever since to "iron out" irregularities in metal forming and to insure that the final fixturing for welding will bring the parts in intimate contact.

The reinforcing bands are also carefully inspected for flatness, roll-over and burrs to insure close contact when located in the welding fixture.

2. *Heat Input and Joint Design.* The desirability of achieving suitable weld size with a minimum of heat input was given further consideration and this resulted in adding a $^1/_{32}$ in. step in the wheel and

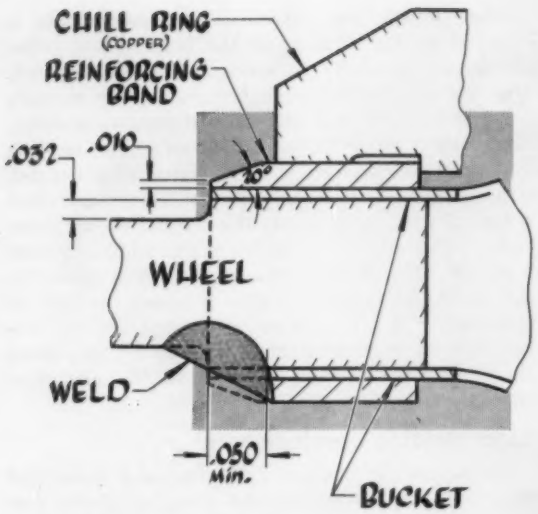


Fig. 8—Final joint configuration

a 20 deg chamfer to the reinforcing band as shown in Fig. 8 which represents the final joint configuration. At that time stress calculations showed that the weld penetration at the bucket-to-wheel junction could be established at 0.050 in. minimum.

To further reduce heat input, the electrode-to-work spacing was reduced to 0.010 in., with the tungsten electrode located only $^1/_{32}$ in. from the inside diameter of the copper chill ring.

3. *Fixturing Details.* Figure 9 shows an as-welded wheel before removal from the welding fixture. This fixture is made to close tolerances and hardened before final machining. A central dowel locates the wheel, with the bottom reinforcing ring (during both welding operations) resting on an annular anvil. The top member incorporates a copper chill ring which locates the reinforcing band and applies a positive pressure near the ID to give an effective and consistent heat sink. *The control of band extension from the copper ring, and the correlation of welding current so as to bring the weld fusion line near the chill ring (giving a minimum of work extension at the time of metal solidification) have been important factors in the control of incipient crack progression.*

The electrode holder is turned 15 deg from vertical (as shown), and the electrode is 0.093 in. diam 2% thoriated tungsten ground to a sharp point. At the start of every run the electrode location is adjusted as stated above, using feeler gages. Welding is performed with argon at a flow of 10–12 cfh.

4. *Gas Shielding.* The original problem of incipient crack progression was also associated with some small oxidized porous zones at the boundary of weld fusion. It was concluded that significant protection against oxidation and control of crack progression could be achieved by backing the parts with an inert gas. Means were provided for applying helium gas backing, and this has also been used on all subsequent fixturing. Figure 9 shows the

Fig. 9—Welding set-up showing fixtured wheel, helium gas line (for backing), inert arc holder and manipulator

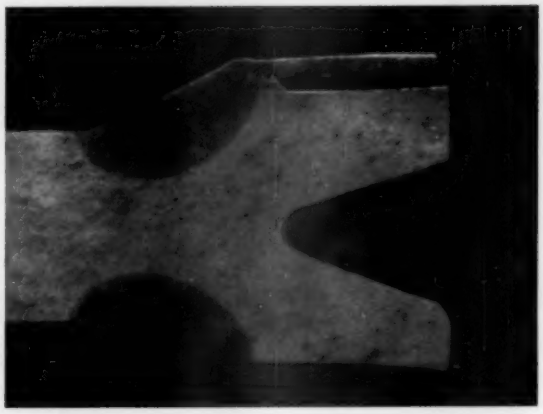


Fig. 10—Section of wheel rim after destructive overspeed test—× 8 (reduced 15% on reproduction)

Tygon tube which feeds the gas into the fixture. A bottom annular manifold is connected to a top manifold so as to permit a "bleeding" of gas by the misfits between bucket bases, wheel teeth and reinforcing bands. Slots are provided in the fixture washers to give increased parallel flow to enhance flushing of the manifolds prior to welding and to limit back pressure. Flushing is performed during the locating of parts and during bolting and electrode

(a)

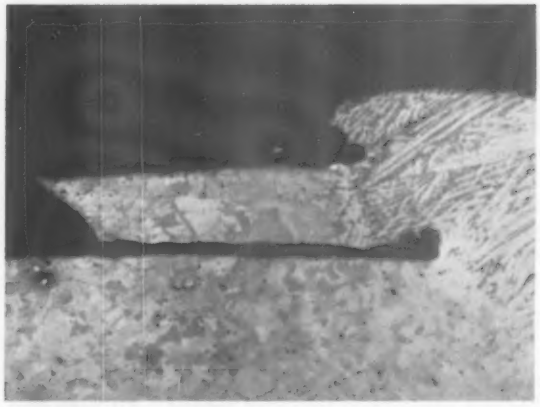


Fig. 11—Cross sections of welded joints after destructive overspeed tests —× 60 (Reduced 15% on reproduction)

adjustments in order to displace air prior to welding. Destructive tests have proved the value of this gas backing in weld quality improvement, with the best results being obtained in the 10–20-cfh flow range.

5. *Heat Treatments.* Prior to assembly and welding, all buckets are solution treated at 1950° F in a vacuum. This eliminates all forming stresses, so that final aging response will be uniform, and it also renders the parts exceptionally bright and clean.

Wheel forgings are supplied in the stress equalized condition, and the reinforcing bands are purchased in the form of sheet stock in the solutioned condition.

After welding, the assembly is given a stress equalization treatment to minimize residual stresses that might enhance cracking during the aging process. This operation is performed at 1625° F for 2 hr in a pusher-type hydrogen furnace which permits very fast heating and cooling through the aging heat range. Final aging is performed at 1300° F for 20 hr in an argon atmosphere. This results in an assembly where the wheel exhibits a hardness in the 33–39 Rockwell "C" range, while the buckets meet or exceed a tensile strength of 155,000 psi (yield strength 100,000 psi minimum).

Final Results

The adoption of the above procedures has resulted in the ability to produce welded wheels which consistently meet the destructive and nondestructive tests reported hereinafter. Extensive sectioning and metallographic studies have proved the effectiveness of procedures that have now become standard. Figure 10 shows conditions near the rim of a finished wheel which has been given an overspeed test and where *bucket failure occurred at a speed in excess of 87,000 rpm.* (This wheel was identical to the one shown in the lead photograph of this article.) The weld configurations and heat-affected zones are shown as well as the triangular groove in the rim which is added to reduce weight and inertia and to reduce wheel stress. In addition to the bucket failure, one of the reinforcing bands has completely failed while the other has only started to fracture.

Figure 11 both magnifies the failure in Fig. 10 and shows another bucket section from the same wheel which exhibits exceptional ductility in the weld metal. It shows that considerable stretch has occurred in the dendritic structure before the bucket base necked-down and failed about $^{1}/_{32}$ in. from the fusion line. Conditions such as these confirm the suitability of the fabricating and heat-treating procedures and indicate the expected performance of the units.

Tests for Performance

Thermal Cyclic Bucket Tests

During the early development stages, considerable attention was focused upon the methods of bucket forming and especially upon a condition of folds which occur where the leading and trailing edges of the scoop are swaged to a sharp condition. Studies were made to determine the effect or need of annealing between forming operations, which are accomplished in several "strikes." It was determined that these anneals were not needed. However, because of lack of operating experience, it was considered advisable to initiate some severe thermal impact tests to evaluate bucket life in general.

A wheel was fabricated, aged, and set up in a special automatic cyclic flame tester which was designed for tests such as these. Oxyacetylene burners were adjusted to concentrate heat upon

Table 2—Thermal Cyclic Bucket Tests

Tests	Time to heat, sec	Maximum temperature, ° F	Time to cool, sec	Minimum temperature, ° F	No. of cycles
1st group	6	1100	6	200	500
2nd group	6	1100	6	200	1000
3rd group	6	1500	6	350	1000

Table 3—Overspeed Tests

Wheel stage	"Fail-safe" holes	Calculated failure speed, rpm	Maximum speed at failure, rpm	Final condition
1st	Yes	60,000–67,000	65,000	2 buckets failed
2nd	Yes	60,000–67,000	64,080	All buckets failed
1st	No	.....	87,720	All buckets failed
2nd	No	.....	78,000	All buckets failed

three adjacent bucket blades, the central one being instrumented for temperature. The hot gas was applied normal to the surface of the wheel so that it was concentrated on the leading edges of the group of buckets. A continuous testing cycle was set up based on the time and temperature limits shown in Table 2. After testing, representative cross sections of bucket blades were given microscopic examination to compare with original conditions. It was concluded that these tests had not propagated cracks from the folds that were present due to forming.

Endurance Testing

During the development program, one wheel was manufactured to the production design and used for checking over-all pump performance. This wheel was assigned to many miscellaneous tests runs and, in all cases, it has performed to schedule without incident.

Overspeed Tests (Basic)

The J-93 afterburner pump employs a two-stage turbine. This means that the development disclosed in this paper actually covered two turbine wheels of slightly differing configuration. The first stage wheel (shown in the lead photograph) employs 97 tubular buckets, while the second stage wheel employs 90 buckets of somewhat greater length and different configuration. (Fig. 1 shows basic differences.) Since the welded joint configurations, fit-up, fixturing and outside diameters are similar for both wheels, no differentiation has been made up to this point. However due to differences in bucket length and operating stress, the maximum overspeed test conditions do differ for the two stages as will be shown.

During the developmental program it was decided that both wheels should incorporate a "fail-safe" design so that, in a case of catastrophic overspeeding, a wheel would shed its buckets without bursting into larger fragments. This is accomplished by weakening the bucket base with punched holes, the size of which is determined by operating stress calculations. The lead photograph shows the final design of first-stage buckets containing four "fail-safe" holes. (The second-stage buckets employ only two holes.) The desirable bucket-shedding speeds for both of the designs is in the 60,000–67,000 rpm range.

To prove the designs and to determine the basic bursting speed, wheels of each stage were oversped to destruction with both "fail-safe" and solid-base buckets. Table 3 summarizes these tests, and it should be noted that bucket shedding occurred for each type very near the median of the desired speed range. The indicated basic catastrophic overspeed values (for buckets without holes) are far above design requirements, with the first stage attaining the higher speed due to its shorter buckets.

Routine Production Tests for Weld Quality

1. *Hardness Tests.* All wheels are given a hardness test after final aging to determine the response of the material to the treatment. The required hardness is in the 33–39 Rockwell "C" range.

2. *Dye Penetrant Inspection.* All wheels are subjected to dye penetrant inspection at the weld zones with no visible defects allowed.

3. *Production Overspeed Tests.* All wheels (both first and second stage) are given a 55,000 rpm overspeed test with a maximum allowable diametrical "stretch" (at bucket tips) of 0.001 in. as a result of this test.

4. *Fluorescent Penetrant Inspection.* All finished wheels are given fluorescent penetrant inspection in accordance with company and military standards.

Discussion

This paper has presented pertinent information with respect to welded turbine wheels employing buckets made from thin-wall tubing. All tests and performance data indicate that they will successfully meet all requirements in driving the afterburner fuel pump for a Mach-3 aircraft engine. Weight and cost savings are realized.

While this model is limited to operational temperatures in the 1000–1200° F range, it is planned to explore the possibilities of expanding this design concept using materials suitable for higher temperature service.

Acknowledgments

The author wishes to recognize E. K. Bullock, Project Engineer; E. G. Allen, Turbine Design Engineer; and R. A. Lanciano, Advanced Manufacturing Engineer for collaboration in turbine design, stress analyses and metals forming. Grateful recognition is also given for valuable metallurgical and heat-treating contributions by personnel within the author's unit, with especial recognition for his associate, W. C. Stairs, for excellent technical support in the development of welding schedules and tooling.

Reference

1. Rosenberg, A. J., and Jamison, E. W., "Automatic Welding of Aircraft Accessory Turbine Wheels," THE WELDING JOURNAL, 37 (4), 328–335 (1958).

Practical Welder and Designer

Welded Steel Office Buildings

BY JOHN F. GULLEY

All-welded multifloor office buildings erected in Baltimore for the State of Maryland are noteworthy not only for their clean, modern architectural lines but also for the introduction of some unusual beam-to-column welded connections.

One of the structures is a 6-story unit for the State Roads Commission. A second 15-story building houses state offices transferred from Annapolis—Fig. 1. These required 700 tons and 3500 tons of welded structural steel, respectively Trim is limestone, with spandrels of blue-green glass and aluminum dividers. Third in the group is a 6-story Employment Security Building.

The latter, erected by the Arthur Phillips Co., Maryland's largest steel erector, was designed for welded construction by Green Associates of Baltimore. Since all bidders were on an equal footing, the only opportunity an erector had to effect economies was in the method of erection and in welding procedures. For this reason, Phillips chose long-boom cranes instead of derricks for handling steel into place. Starting at the north end, the structure was built up to full height at each column line, backing down the length of the building one bay at a time.

The job called for welding some 1500 tons of structurals, as well as 300,000 sq ft of cellular flooring. It was decided to tap power from the lines of Baltimore Gas and Electric Co. to insure a steady and trouble-free supply.

Twelve welding machines were employed to maintain the erection schedule. Three were 300 amp a-c, d-c covered-electrode units, six were 400 amp a-c units, and two were 200 amp d-c engine-driven welders mounted on undercarriages for portability while the twelfth was a standard 300 amp d-c motor-generator set.

Electrode consumption ran to 11,000 lb for both framing and flooring. Around 6000 lb of $^{3}/_{16}$-in.

JOHN F. GULLEY is Field Engineer, The Lincoln Electric Co., Baltimore, Md.

Fig. 1—One of three new all-welded steel buildings erected for the State of Maryland in Baltimore. This is a 15-story unit for state offices, requiring 3500 tons of structurals

Fig. 2—Typical beam-to-column connection, with backup plate welded across the column flanges. Note how web and flange are flared out to match section of opposite beam

Fig. 3—Vertical butt weld connecting beam web to column web. Iron-powder electrode and a-c current speeded production time on these joints by an estimated 30%

diam E-6011 electrodes were required for vertical fillets, root passes and incidental tacking and welding. This rod was chosen because of its adaptability to both a-c and d-c current. For heavy butt welds as on all beam-to-column connections, a-c machines were used in combination with E-6027 electrodes of $^{5}/_{16}$ in. diam. About 5000 lb of the latter were consumed. This high-speed rod made possible a 30% saving in over-all production time when checked against bid estimates. In addition to faster deposition rates, the combination of iron-powder electrodes and a-c current minimized arc blow conditions characteristic of deep-groove welding and resulted in smooth bead appearance and sound welds, obviating costly cutouts and rewelding after inspection.

General erection procedure called for shop welded erection seat angles on the column, against which beams could be rested and then bolted temporarily to the column. Backup plates were tack welded into the web of the column and the beam, as indicated in Figs. 2 and 3. With a 45 deg chamfered bevel on the beam flange, a root pass was made with E-6011 electrodes and four succeeding passes with E-6027.

As shown in Fig. 2, stiffener plates were welded from the ends of the beam flanges, top and bottom, into the web of the column, serving to carry the section modulus of the beam through the column and make a continuous connection. Where shallower beams joined into deeper sections, triangular pieces were welded into the end and the bottom flange depressed to bring the connecting face to the same depth as the adjoining beam. In some cases, it was necessary to depress the top flange slightly by cutting out the web to make the connecting face match that of an adjoining beam.

Stainless Steel Coil Permits Internal Cooling of Unique Welder Ignitron with Help of Tungsten-Arc Welding

A unique internal cooling coil construction for welder ignitrons developed by National Electronics, Inc., Geneva, Ill., depends on stainless steel tubing for arc-back-free operation and long service life. The ignitrons are metal, water-cooled, mercury pool vacuum tubes designed especially for welder control and similar a-c control applications.

Because the tubes contain mercury and mercury vapor, any material with which readily amalgamates cannot be used for the coil. The material also must prevent oxidation from water passing through the coil. Such oxidation would release nascent hydrogen, which could penetrate the wall of the tubing and destroy the vacuum inside the ignitron.

To solve these problems, Type 304L stainless steel tubing was selected, in that this stainless grade eliminates danger of oxidation or amalgamation with the mercury.

Forming of the stainless tubing into coils is done quickly and simply on a drum type tube bending machine. For its two ignitron models, two sizes of tubing are used—$^{5}/_{8}$ in. OD x 0.065 in. wall x 20 ft long and $^{3}/_{4}$ in. OD x 0.065-in. wall x 28 ft long.

After the coils are wound and the ends formed, one end is closed by tungsten-arc welding. The coil is

Based on a story from the Carpenter Steel Co., Union, N. J.

placed on a vacuum pump and evacuated. After a suitable vacuum is obtained, the coil is clamped off and checked for air leaks. During pumping, the coil temperature is raised from room temperature to approximately 800° C while the ignitron is being evacuated. The cooling coil is water tested at 125 psi.

No machining operations are performed on the stainless tubing during the entire fabricating process. Once the coil is wound and tested, it is tungsten-arc welded to cold rolled steel plates on the ends of the ignitron tube. Copper water fittings are brazed to the stainless. A thermostat mount is brazed solidly to the cathode heater and cooling coil to provide accurate temperature indication and tube protection.

In service, the ignitrons operate at a maximum 1500 v and carry a maximum current of 900 amp. For short pulse durations the current can be considerably higher than this figure. Temperature variations on the coil range from about 0 to 100° C during operation. Water pressure in the cooling coil varies from about 20 to 45 psi.

Fig. 1—Grooved drum fixture mounted on a lathe is used to form Type 304L stainless steel tubing into cooling coil for welder ignitron

Fig. 2—Anode header assembly is gas-tungsten-arc welded to stainless steel cooling coil at National Electronics, Inc., Geneva, Ill.

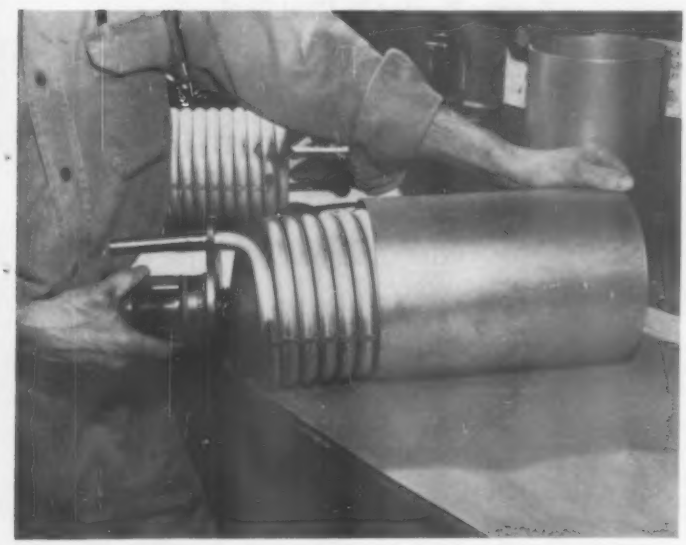


Fig. 3—Stainless steel cooling coil and header assembly are inserted into outer envelope of ignitron, also made of stainless steel

Fig. 4—Cooling coil in the completed ignitron is water tested at 125 psi for cooling efficiency; the unit is a mercury pool tube designed especially for welder and similar a-c control applications

Workmen on the roof of the UEC building, scheduled for completion in August, lower metal coverings for outside walls

UNITED ENGINEERING CENTER

Top . . . to Bottom

In the basement a welding operator joins a section of pipe in the building's heating system

Honor Sections

Section	Goal, %	Section	Goal, %
Oklahoma City	125	Long Island	100
Mahoning Valley	113	Louisville	100
Holston Valley	109	Madison-Beloit	100
Cincinnati	104	Maryland	100
Hartford	104	Michiana	100
Kansas City	102	Nashville	100
N. E. Tennessee	102	New Hampshire	100
Puget Sound	102	New Jersey	100
Tulsa	102	N. Central Ohio	100
Baton Rouge	101	North Texas	100
Colorado	101	Northern N. Y.	100
Detroit	101	Northwest	100
Niagara Frontier	101	Olean-Bradford	100
Providence	101	Pascagoula	100
Rochester	101	Philadelphia	100
San Diego	101	Richmond	100
St. Louis	101	Salt Lake City	100
Birmingham	100	San Antonio	100
Boston	100	Sangamon Valley	100
Bridgeport	100	Santa Clara Valley	100
Chattanooga	100	Syracuse	100
Dayton	100	Toledo	100
Eastern Illinois	100	Western Mass.	100
Iowa	100	Wichita	100
Long Beach	100	Worcester	100

Pledges Needed to Meet Goal

Section	Needed	Section	Needed
Mohawk Valley	100	New Orleans	390
Tri-Cities	100	York-Central Pa.	435
Albuquerque	150	Fox Valley	450
Anthony Wayne	150	Saginaw Valley	460
Shreveport	195	Lehigh Valley	475
Arizona	200	Portland	485
Nebraska	200	Indiana	490
Washington	200	Stark Central	495
New York	218	Columbus	790
Carolina	245	Northwest	822
Northwestern Pa.	280	Milwaukee	917
J. A. K.	295	San Francisco	1008
Mobile	300	Cleveland	1090
Peoria	340	Houston (and Sabine)	1540
Susquehanna Valley	350	Chicago	1590
Western Michigan	350	Pittsburgh	2116
Iowa-Illinois	370	Los Angeles	2825
South Florida	370		

Several new sections appear on the Honor Roll for having achieved 100% or better of their goal. However, AMERICAN WELDING SOCIETY pledges stand at 71% of goal.

Society News

A. F. Chouinard Elected 1961–62 AWS President

Newly-elected officers of the AMERICAN WELDING SOCIETY for 1961–62 were feted by AWS members attending the 42nd Annual Meeting and Exposition held in New York April 17 to 21.

A. F. Chouinard, director of research and development, National Cylinder Gas Div., Chemetron Corp., Chicago, Ill., was elected president of the SOCIETY following R. D. Thomas, Jr., president of Arcos Corp., whose term expires May 31, 1961. Mr. Chouinard is currently completing a term as vice president. He will assume his new duties together with other officers-elect on June 1st, when the new term officially begins.

Three vice presidents were elected: Jay Bland, manager, Welding Development at the General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N. Y.; John H. Blankenbuehler, design engineer, Hobart Brothers Co., Troy, Ohio; Clarence E. Jackson, associate manager, Electric Welding Development, Linde Co., Div. of Union Carbide Corp., Newark, N. J.

Newly-elected directors-at-large for the new fiscal year are: J. E. Dato, general sales manager, Electric Welding Dept. Linde Co., Div. of Union Carbide Corp., New York, N.Y.; A. N. Kugler, chief welding engineer, Air Reduction Sales Company; T. E. Jones, president and treasurer, Precision Welder & Machine Co., who holds the same offices in Precision Welder & Flexopress Corp. and Precision Welder & Flexopress, Ltd. (Canada); E. C. Miller, inspection engineer, Oak Ridge National Laboratory, operated by Union Carbide Nuclear Co., for the Atomic Energy Commission, Oak Ridge, Tenn.

District directors for the new term are: *Middle Eastern*, District 2, C. L. Kreidler, chief engineer, Lehigh Structural Steel Co., Allentown, Pa.; *East Central*, District 5, P. J. Rieppel, chief, Metals Joining Div., Battelle Memorial Institute, Columbus, Ohio; *Midwest*, District 8, George O. Bland, president, Hill Equipment Co., St. Louis, Mo.; *Northwest*, District 11, W. J. Erichsen, manager, Metallurgical Laboratory, Westinghouse Electric Corp., Pittsburgh, Pa.

A. F. Chouinard

The National Nominating Committee will consist of R. D. Thomas, Jr., chairman, C. I. MacGuffie, R. C. Becker, A. E. Pearson and the 11 district representatives.

The new district representatives who will serve on the National Nominating Committee for the 1961–62 term are as follows:

G. W. Kirkley, 1086 Dryden Rd., Columbus 5, Ohio (No. 1); James Cameron, ACF Industries, Inc., Berwick, Pa. (No. 2); David Peter-

VICE PRESIDENTS

Jay Bland

J. H. Blankenbuehler

Clarence Jackson

son, Air Preheater Co., Wellsville, N. Y. (No. 3); R. E. Lorentz, Jr., Combustion Engineering, Inc., 911 W. Main St., Chattanooga 1, Tenn. (No. 4); R. J. Yarrow, 1324 Irene Rd., Cleveland, Ohio (No. 5); Keith Sheren, Taylor Thompson Machinery Co., 8095 Livernois, Detroit 4, Mich. (No. 6); C. K. Seitz, Welders Supply, 111 Barrett Pl., Beloit, Wis. (No. 7); C. R. Reardon, assigned engineer, Sheffield Div., Armco Steel Corp., Kansas City 25, Mo. (No. 8); D. J. Middlehurst, Big Three Welding Equipment Co., P.O. Box 3047, Houston, Tex. (No. 9); J. B. Ross, 11049 Kling St., N. Hollywood, Calif. (No. 10); and R. E. McCormick, sales manager, Pacific Metals Co., 1900 3rd St., San Francisco, Calif. (No. 11).

In addition to the newly-elected officers, the following national officers will continue in office:

Directors-at-Large: F. G. Singleton, C. B. Smith, J. R. Stitt, R. B. McCauley, John Mikulak, E. F. Nippes and R. D. Stout. Since Mr. Bland has been elected a vice president, the unexpired portion of his term (1962) will become vacant.

District Directors: G. W. Kirkley (No. 1), J. W. Kehoe (No. 3), J. M. Shilstone (No. 4), R. H. Hoefler (No. 6), L. L. Baugh (No. 7), C. L. Moss, III (No. 9), and D. P. O'Connor (No. 10).

Past-president Directors: R. D. Thomas, Jr. and C. I. MacGuffie.

DIRECTORS-AT-LARGE

J. E. Dato

A. N. Kugler

T. E. Jones

E. C. Miller

DISTRICT DIRECTORS

C. L. Kreidler
District 2

P. J. Rieppel
District 5

George O. Bland
District 8

W. J. Erichsen
District 11

KEEPING YOU POSTED

By Fred L. Plummer

● Early in March the Long Island Section became the 50th AWS Section to fully meet its quota in the United Engineering Center Fund Drive. At that time only eight Sections needed pledges in excess of $500 to meet their goals.

● District Directors George Kirkley, Joe Kehoe and Cliff Moss in letters dated March 6th or 8th, and addressed to officers of Sections in their Districts, have summarized plans for educational programs, Welded Products Month, membership recruitment, the UEC fund drive, section visits and programs and other section and district activities. These and other district directors have given unusually effective leadership in their respective areas.

● Announcement of "Welded Structural Design," 1961 lecture series sponsored by the Pittsburgh Section, brought so many applications that it became necessary to find a larger auditorium in order to accommodate the "limited" registration of 300 participants, according to C. W. Lytton. The lectures, held March 7th, 8th, 14th, and 15th, covered "Structural Steel Joints," "Continuous Elastic Design." "Welded Plate Girders" and "Distortion Control."

● The annual education course conducted by the Detroit Section resulted in the addition of more than 60 new members to AWS and firmly re-established Detroit as our largest and certainly one of our most active Sections.

● These two examples are typical of the very large number of very popular and effective courses planned and conducted by our Sections to provide authoritative information about and encourage the greater use of welded fabrication. During the current fiscal year many thousands of engineers, architects and supervisory personnel will benefit from such courses. It is hoped that within the next few years every AWS Section will include at least one such course in its yearly program of activities.

● During March a group of men interested in welding recruited more than fifty AWS members and requested the forming of a Greater Huntsville Section. Your Secretary plans to attend the initial meeting of this Section which has been scheduled for March 25th by Activation Chairman E. J. Wilson.

● ASM Executive Ted DuMond visited with your Secretary and President Thomas at AWS headquarters on February 23rd to discuss several areas in which the two Societies might cooperate more effectively. This conference followed previous talks your Secretary has had with ASM Managing Director Ray Putnam.

● This same day President Thomas, Past-president J. H. Humberstone, who is chairman of your Headquarters Housing Committee, and your Secretary met with United Engineering Trustees and representatives of other groups which will establish their national headquarters in the new United Engineering Center. It is now expected that construction of the Center will be completed during August and that "move in" day may be about Sept. 1, 1961.

● The following day some 40 members of the American Council of the International Institute of Welding gathered in New York for a meeting of the Council and later of its Executive Committee with your Secretary serving as chairman and E. A. Fenton as secretary. Several Commission groups held independent meetings at the call of their U. S. chairman.

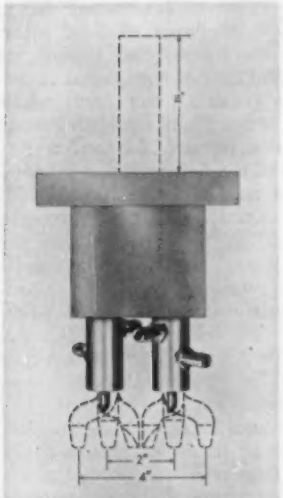
● Long-time AWS member in the Pittsburgh area, Malcolm Priest visited your Secretary on February 27th. Mr. Priest, retired after many years of service to U. S. Steel Corp., is now devoting approximately half of his normal work time as consultant to two major industrial concerns.

● Preparations for the Annual Assembly of the International Institute of Welding superimposed upon those for the AWS Annual Meeting and Welding Exposition created unusually heavy assignments for all AWS staff members during March and April. Assistant Secretary Frank Mooney was responsible for preparing programs and list of participants, arranging for group breakfasts, lunches, dinners and receptions, boat excursion and other special events; Ted Schoonmaker arranged for meeting rooms, equipment and supervision; Ed Fenton was in charge of the large staff of interpreters, secretaries and typists, as well as the special equipment necessary to produce the tremendous volume of documents in both French and English required for the four day sessions of the fifteen technical commissions as well as those for the Executive and Governing Councils; Art Phillips was responsible for publicity and public relations involving newspapers, trade magazines, technical journals, radio, television, interviews, photographs, special brochures, certificates and medals; Ed Krisman handled hotel reservations and the several hundred advance enrollment forms received from the 28 member nations covering participation in all special activities including opera, symphonies and theater.

● President R. D. Thomas, Jr., addressed a joint meeting of the Mobile and Pascagoula Sections on March 9th, discussing the electroslag and electrogas welding processes. Chairman John Milandin presided at the meeting as Program Chairman E. H. Holden introduced President Thomas.

● The following night your Secretary joined President Thomas at a meeting of the Richmond Section. J. G. Jones met your Secretary at the airport and escorted him first to the Mark Monroe Hotel and later

Double-Barrelled Tip Holder Makes Two Equal-Pressure Welds



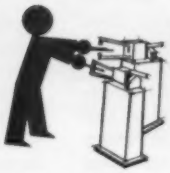
Absolute fidelity of spacing between welds, in a range from 0 to 4", is accomplished by using Tuffaloy bent offset tips as diagramed above.

*Airco trademark

The TUFFALOY Equa-Press* Dual Holder makes two spot welds at once, and makes them precisely alike. Upon contacting the work piece, the forging pressure is automatically equalized between the two electrodes, regardless of minor variations in work thickness or electrode wear (up to 3/16").

The two tip-holding barrels are sliding pistons, whose movements are controlled by a mechanical equalizing device sealed in the housing. Maximum conductivity is maintained through the copper-alloy working parts, and water coolant fittings are provided.

Models are made for mounting in a welder arm (above) or for bolting to a press welder platen (left).



Doc Tuffy says . . . you'll almost double your output of closely-spaced welds without adding a man, with the TUFFALOY Equa-Press Dual Holder!

There is an AIRCO or TUFFALOY distributor near you. Call him and ask to see the Equa-Press Dual Holder. Ask him too for the TUFFALOY Catalog . . . it makes correct resistance welding electrode specifications easy.

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For details, circle No. 8 on Reader Information Card

to Cox's Restaurant (Carl Schaub performed a similar service for President Thomas) for a social period, dinner and the technical meeting. Vaughan Calder introduced both your Secretary who spoke briefly and President Thomas who discussed dramatic applications of stainless and low-alloy steel welding. Chairman C. G. Dillard and Section Officers W. W. Morris, J. Jones, J. Tepper and W. Dysen conducted this well attended and carefully planned meeting.

● President-elect A. F. Chouinard spent March 15th with your Secretary discussing committee appointments for the 1961–62 fiscal year, making tentative plans for Section visits during this same period, considering new projects and expansion of established activities, and reviewing details of his participation in national and regional meetings.

● The following morning National Membership Chairman H. E. Miller and Vice Chairman Andy Axtell met with President Thomas, President-elect Chouinard, Assistant Secretary Frank Mooney and your Secretary to plan membership activities during the remainder of the current and for all of the 1961–62 fiscal year. The total membership in the SOCIETY has reached a figure higher than at any previous time during its 42 year history.

● During the afternoon Past-president C. I. MacGuffie, President Thomas, Vice-presidents Chouinard and Jackson (Blankenbuehler was unable to be present), constituting the Office Assignment Committee, met to prepare recommendations covering the assignment of 1961–62 Board of Director members to the Executive and Finance Committee, the Administrative Council, the District Council, the Publication and Promotion Council and the Technical Council. These recommendations will be presented to the Board of Directors for approval at their June meeting.

Welcome

• Supporting Company

Effective May 1, 1961:

Liquid Carbonic Div., District Sales Office
General Dynamics Corp.
Detroit, Mich.

AMERICAN WELDING SOCIETY
INCORPORATED

33 WEST 39TH STREET • NEW YORK 18, NEW YORK

A NON-PROFIT ORGANIZATION

FOUNDED IN 1919 FOR ADVANCING THE SCIENCE AND THE ART OF WELDING

FRED L. PLUMMER
NATIONAL SECRETARY

PENNSYLVANIA
6-9220

May 1, 1961

AN INVITATION TO AUTHORS

—to participate in the American Welding Society's

43rd ANNUAL MEETING AND EXPOSITION

Cleveland, Ohio, April 9–13, 1962

Gentlemen:

The American Welding Society will hold its 43rd Annual Meeting and Exposition in Cleveland, Ohio, on April 9–13, 1962.

Each year our Society offers opportunities to Authors for bringing their outstanding work, development and research to the attention of our Membership and the welding and metals industry, by having previously unpresented and unpublished papers presented at its national meetings.

The Society's Technical Papers Committee will be happy to receive your application for entry in the 43rd Annual Meeting activity. All applications, abstracts and manuscripts will be screened by the Committee, and Authors will be notified sometime in October 1961 regarding acceptance.

Each abstract should be sufficiently descriptive to give the Committee a clear idea of the content of the proposed paper. In any case, it must contain *not less than 500—but preferably not more than 1000—words.* Also, in order to place the Committee in the best possible position to evaluate these papers, it is suggested that each abstract be accompanied by a complete manuscript.

The Committee reserves the right to consider all applications on the basis of acceptance for placing on the 43rd Annual Meeting program, or consideration for placing on the 1962 National Fall Meeting program, the next national meeting of the Society. Papers may be considered for publication in the *Welding Journal* regardless of acceptance for presentation at either Meeting.

Papers dealing with latest developments in (1) design and fabrication of all types of weldments, including machinery, (2) welding of aircrafts and rockets, (3) fabrication and maintenance of equipment used for radioactive applications, (4) pressure vessels and storage tanks, (5) equipment and pipe lines used in petroleum industry, (6) structures, (7) automation as applied to welding processes, (8) resistance spot, seam and projection welding, (9) gas-shielded arc welding, (10) new processes, (11) welding of castings and composite structures, (12) welding of "new" alloys, (13) weldability of high-strength steels, (14) welding of aluminum, magnesium, zirconium, titanium, molybdenum and like metals, (15) brazing, (16) maintenance, (17) surfacing, (18) soft soldering, (19) adhesive bonding, (20) welding of plastics, and (21) practical applications or "how-to-do" topics are deemed to be of particular interest at the Cleveland meeting. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy, are welcomed as long as the subject falls within the field of our Society's activities.

Please fill out the Author's Application Form on reverse side of this letter, attach abstract thereto, and return to AWS. To assure consideration for the 43rd Annual Meeting program, your abstract must reach AWS not later than August 15, 1961.

Sincerely,

Fred L. Plummer

Fred L. Plummer
National Secretary

IMPORTANT: ABSTRACTS CONTAINING LESS THAN 500 WORDS AND THOSE POSTMARKED LATER THAN AUGUST 15, 1961, WILL NOT BE CONSIDERED.

AUTHOR'S APPLICATION FORM
FOR
AWS 43rd ANNUAL MEETING
APRIL 9-13, 1962

DEADLINE
AUGUST 15
1961

Complete in Full and Return to American Welding Society, Inc., 33 West 39th Street, New York 18, N. Y.

Date Mailed.....

Author's Name.....

Company or Organization.....

Title or Position.....

Mailing Address.....City.....State.....

If there are to be Joint Authorships, give name(s) of other author(s)

Name .....
Address .....
Name .....
Address.....

PROPOSED TITLE (10 words or less): _____

_____

SUBJECT CLASSIFICATION:

- Classify your paper by placing check mark in appropriate box:
  Industrial Application ☐ Engineering or Design Data ☐ Process Development ☐ Shop Practice ☐
  Original Research ☐ Education ☐ Other ☐ _____ (state which)

ABSTRACT:

- Type, single spaced, an abstract of *not less than 500—but preferably not more than 1000—words* on separate sheet and attach to this form. Be sure to give sufficient information to enable Technical Papers Committee to obtain a clear idea of content of proposed paper.
- If complete manuscript is available, in addition to abstract, please attach copy hereto.
- Application Form and Abstract *must* reach AWS Headquarters not later than August 15, 1961, to assure consideration for 43rd Annual Meeting.

MANUSCRIPT DEADLINES:

- All manuscripts *must* be in the hands of the Technical Paper Committee not later than February 15, 1962. If received prior to December 15, 1961, every effort will be made to publish them in advance of meeting.
- It is expected that the Committee's selections will be announced sometime in October, 1961.
- If your paper is made a part of the program, which of the following manuscript deadlines will you be able to meet?
  December 15, 1961 ☐ January 15, 1962 ☐ February 15, 1962 ☐
- If manuscript is attached hereto, please check here ☐

PRESENTATION AND PUBLICATION OF PAPERS:

- Has material in this paper been previously presented in meeting or published?
  Yes ☐ No ☐ When?_____ Where?_____
- Following presentation at the Society's 43rd Annual Meeting, would you accept invitation to present this paper before AWS Sections? Yes ☐ No ☐
- Papers accepted for presentation become the property of the Society, with original publication rights assigned to the *Welding Journal*.

RETURN TO AWS HEADQUARTERS. MUST BE RECEIVED **NOT LATER THAN AUGUST 15, 1961,** *TO ASSURE CONSIDERATION.*
ABSTRACT MUST CONTAIN NOT LESS THAN 500 WORDS.

_____
Author's Signature

EDUCATIONAL ACTIVITIES

Fall Meeting

Last fall, in Pittsburgh, we held an educational open meeting in the morning, and a publicity open meeting in the afternoon. Both were well attended and accomplished a lot. The Educational and Publicity Committees felt that the time had come for genuine "how-to-do-it" sessions—meetings where members with experience in some particular phase could explain the various steps necessary to obtain a given objective.

One speaker outlined the steps necessary to present a successful educational course. He was speaking from personal experience because his section had just completed a very successful course. Another speaker discussed how to organize a two-day seminar—the difficulties, the points to watch, how to promote, how to obtain attendance and the type of speaker who does the best job.

The publicity open meeting went even further along the "how-to-do-it" path. The session included: how to write news releases, how to obtain publicity, how to publicize and what to publicize.

The chairmen of the various section activities are usually elected for a single year. This means that each incoming chairman usually has to learn the job right from the beginning. It becomes increasingly clear that help must be provided to enable these new chairmen to make a success of the job they have undertaken. These open meetings are a start and have already proved their worth.

Two sections holding educational courses have gained a considerable number of new members as a result of the courses. One section educational chairman hit the nail right on the head when he said, "If you can provide what is needed you'll have no difficulty in obtaining new members."

Many more sections promoted National Welded Products Month this year. This was a direct result of the interest in, and attendance at, the publicity open meeting last fall. Many have stated that it put them on the right track, and the *Planning Manual* gave them the additional help they needed.

The next Fall Meeting is in Dallas in September. All educational and publicity chairmen should attend if at all possible. If circumstances prevent attendance, make sure that someone from the section attends.

The success of your section next year may well depend upon the techniques you learn at the Fall Meeting. A successful educational course can bring many new members—the Detroit Section obtained 59 new members as a result of its educational course—and publicity is the tool you use to promote your course, your section and your industry.

Welding Handbook, Section 4

In the March issue of the WELDING JOURNAL in the Educational Activities column, the projected contents of the WELDING HANDBOOK were described, and a description given of some of the subjects of the chapters. When the book went to press it was found desirable to hold certain of the chapters over until Section 5 is published, since they fitted better into the format than into one which describes Metals and Their Weldability.

Accordingly, one of the chapters mentioned in the March issue, Filler Metals, will appear instead in Section 5 of the WELDING HANDBOOK, which describes the various applications of welding.

When it was decided to divide the HANDBOOK into five sections it was thought it was desirable to keep each section to a certain phase of welding and make it as nearly complete as possible. Due to circumstances beyond the control of the HANDBOOK editor, this has not been completely possible. In the case of codes or standards, which would be finished a few months after publication of the Section, it was decided to hold that particular chapter over until the next Section since it would be foolish to publish an authoritative book like the HANDBOOK with material which would be out of data within six months. In the Fifth Edition it is hoped that all these discrepancies will be eliminated, and it will be possible to adhere to the original concept of each section covering a particular phase of welding.

There have been many suggestions that the chapter on Filler Metals be reprinted. The fact that it will not appear in the HANDBOOK until the next section is published will not affect any decision to publish it in advance. Because of its value to industry, the chapter on Filler Metals will probably be preprinted in advance of Section 5.

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SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Alabama

BRAZING

Mobile—The February meeting of the *Mobile* Section was held at the State Vocational Trade School on February 21st. Guest speaker at the technical session was R. E. Ballentine, plant manager of the Westinghouse Electric Corp.

Mr. Ballentine defined the basic principles of brazing which clearly illustrated this particular method of joining metals.

Although brazing, as was pointed out, is considered a very simple bonding method, the exact choice of a brazing method becomes complex when grouping all the fields and individual industrial usage together. Expert knowledge is required of the metals to be joined. Physical characteristics, joint design and economy are the major factors in choosing the dried brazing filler metal.

ELECTROSLAG WELDING

Mobile — President R. D. Thomas, Jr., was the guest speaker at the March 8th meeting of the *Mobile* Section, held jointly with the Pascagoula Section. The dinner and technical meetings were held at Cotita's Restaurant in Pascagoula, Miss.

As president of the Arcos Corp., Mr. Thomas spoke on the "Electroslag Welding Process." He opened his talk by defining his process as a relatively new method of welding thick members of steel and alloys in a single pass. These cross sections range from 2 to 15 in. It was emphasized that the cross sections should be constant, although special methods were devised to weld large circular sections.

The Electroslag welding machine as shown by Mr. Thomas implemented fully automatic methods and required the minimum of surface preparation and set-up time. The welded joint requires no after surface preparation due to the controlling surfaces of the machine.

Mr. Thomas exhibited slides showing the components of the Electroslag welding machine and also the comparative advancements and gains in this field.

The "Electrogas" welding process was briefly explained to denote its difference from "Electroslag" welding.

SECTION MEETING CALENDAR

JUNE 7

SUSQUEHANNA VALLEY Section. Annual Dinner. 6:45 P.M. Foot Hills Manor, Shickshinny, Pa.

JUNE 10

ST. LOUIS Section. Annual Golf Tournament. Prizes, refreshments and games. Crystal Lake Country Club.

JUNE 17

OLEAN-BRADFORD Section. Annual Ladies' Night. Dinner-Dance. Music by Dick Jordan.

JUNE 20

DAYTON Section. Annual Picnic. Inland Activities Center.

Editor's Note: Notices for August 1961 meeting must reach JOURNAL office prior to May 20th, so that they may be published in the July Calendar. Give full information concerning time, place, topic and speaker for each meeting.

California

GAS METAL-ARC WELDING

Los Angeles—The *Los Angeles* Section had as guest speaker for the February 16th meeting, Stephen A. Yasko, manager of sales engineering, automatic systems in the Westing-Arc Dept. for Westinghouse Electric Co.

Mr. Yasko's paper on "Gas-Shielded Metal Arc Welding" pertained to the dynamic effect of the welding arc and was accompanied and well-supported with 35-mm slides showing typical automatic and semiautomatic applications.

Approximately 70 members and guests in attendance at this meeting were participated in the question period, the paper being such that it could hold the interest of the

MEETING GETS UNDER WAY

Some of the many guests and members who gathered for the Los Angeles Section February 16th meeting

Two "old timers" were present for the February 16th meeting in Los Angeles. Left to right, they were Francis McGinley, past 10th-district director, and C. P. Sander, past national president

DISCUSSES STRESS RELIEVING

L. J. Larson as guest speaker at the Chicago Section February 17th meeting discussed both stress relieving and welding in Europe

average layman as well as those in a technical or supervisory capacity in the welding field. Following presentation by Mr. Yasko, two high speed 16-mm films were shown—one on the effects of gas mixtures and one on the automation of the welding process as used on the Ford Motor Car Co. production line at Sterling, Mich. Both films were narrated and the automation progressively explained by Mr. Yasko.

Colorado

ANNUAL LADIES' NIGHT

Denver—The February meeting of the *Colorado* Section was held on the 14th at Cavaleri's Restaurant in Denver. In place of the regular meeting this was the Annual Ladies' Night in which the members entertained their wives. The evening began at 6:30 P.M. with cocktails and dinner being served at 7:30 P.M.

Speaker for this event was Byron Lopp, internationally known human relations specialist and sales counselor. Mr. Lopp's topic was "Raising Your Sights for the 1960's." His talk dealt with human relations at home, on the job, in industry and at social activities. His program was presented in a way that was most interesting and entertaining both to the members and their guests. A very nice time was had by all.

Florida

DOOR PRIZE

Hialeah—On March 15th the *South Florida* Section held its regular monthly meeting at the Park Lane Cafeteria in Hialeah. No guest speaker was scheduled.

A movie, entitled "Whatever We Do," was shown through the courtesy of the Air Reduction Sales Co.

As an added interest to their meetings, the section now has a ten dollar door prize. To be eligible to win it, you must be a member in good standing, and be present at the meeting.

Illinois

STRESS RELIEVING

Chicago—At the February 17th meeting of the *Chicago* Section, Louis J. Larson, consulting engineer—welding, read a very interesting paper on "The Case For and Against Stress Relieving" and "Observations of Welding in Europe."

Mr. Larson spoke on a subject in which he truly qualifies as an expert. He discussed the mechanism of stress relieving and conditions where stress relieving is practical and when it is not.

He also showed slides of his personal observations of welding equipment and procedures in shops during his last visit to Europe.

POWER SOURCES

Peoria—Dr. A. Lesnewich of Air Reduction Co. was the guest speaker at the February 15th meeting of the *Peoria* Section. His subject was "Power Sources for Semiautomatic Inert-gas-shielded Welding."

The presentation covered in detail the electrical and operating characteristics of the various types of power sources. His discussion showed that all three—drooping, constant, rising—types of power sources can be used at a given setting for some applications. He then described what happens to the operating characteristics of these power sources as the settings are changed from a given point.

He described the necessity for a drooping characteristic machine for stick electrode welding, and he gave reasons why a CAV machine will not work in this application.

Mr. Lesnewich spent some time discussing tungsten-inert-gas welding and the power source requirements for such work.

He concluded his talk with a short discussion concerning the "short-arc" process, how and why it works and the power source needed for this type of work.

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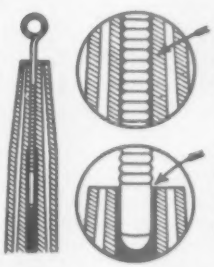

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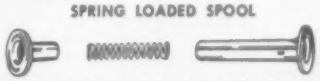

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34	42-41
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Indiana

LADIES' NIGHT

Indianapolis—Fifty-one members and guests enjoyed the annual *Indiana* Section Ladies' Night informal dinner-dance at the Severin Hotel in Indianapolis. A cocktail hour preceded a delicious dinner, which was followed by a short business meeting. Dancing to the music of the Playboys was interrupted occasionally for the presentation of door prizes. Bob Hilburt, who arranged for the affair, also served superbly as master of ceremonies.

GAS PROCESSES

South Bend—The *Michiana* Section met on Thursday, February 16th at Russ Restaurant for dinner and meeting. The technical meeting speaker was Arthur N. Kugler, chief welding engineer, Air Reduction Sales Co., New York, N. Y. His subject was "Fundamentals of Gas Welding, Oxygen Cutting and Brazing."

Mr. Kugler stressed the importance of these basic methods of welding and cutting from the time of their conception and progressing to our present day utilization and possible impacts on our future industrial economy. He said some of the methods at times are considered "old lace," but still the applications today are more varied and utilized more extensively than ever before. Also, he pointed out many gas welding, brazing and cutting jobs which can only be done through these methods. He cited examples of future growth, expansion and cost reduction in industry which necessitates fundamental gas welding and cutting methods. He emphasized that our country's research facilities should be constantly applied to present and forthcoming methods of gas welding and cutting or we will fall behind in industrial progress. This point was demonstrated by Mr. Kugler's "on the spot" descriptions and comparisons with Russia and other European countries' advancements in this field. His informative and greatly appreciated talk was illustrated with slides depicting the old and current methods and applications of gas welding and cutting. These slides were extremely interesting because of his verbal pictorial descriptions telling the "how, what, where and why" of all slides. In closing his unique presentation Mr. Kugler summarized and projected the most important phases of his topic.

Louisiana

STEEL WELDMENTS

Baton Rouge—The *Baton Rouge* Section met on February 16th at the Sherwood Forest Country Club for dinner and meeting and to hear a talk by LaMotte Grover at the Air Reduction Sales Co., New York, N. Y. Mr. Grover discussed the "Control and Correction of Distortion in Steel Weldments."

Attendance prizes were initiated at this meeting. All members in good standing are eligible to win a $10 gift certificate at Rosenfields Department Store. The winner must be present, otherwise he will be advised by phone and $5.00 will be added to the next month's drawing.

GUEST SPEAKER GREETED

Guest speaker for the Peoria Section February 15th meeting was A. Lesnewich of the Air Reduction Sales Co. Left to right are: F. Meyer, J. Carl, Dr. Lesnewich, D. Brugioni and H. D. Smith

Massachusetts

LECTURE COURSE

Cambridge—A successful lecture course on "Welding Metallurgy of Nonferrous Metals and Alloys" was recently completed by the *Boston* Section. Dr. Clyde M. Adams, Jr., associated professor in Metallurgy at MIT conducted the course. The six lectures, held on consecutive Tuesdays from February 21st through March 28th, are a continuation of previous series sponsored by the Section as part of their educational program.

Textbooks used by Dr. Adams were *Welding Metallurgy* by O. H. Henry, G. E. Claussen and G. E. Linnert, *Soldering Manual*, and *Brazing Manual*—all published by the SOCIETY.

Metals and principal alloys of aluminum, magnesium, copper, nickel, titanium, zirconium, molybdenum, columbium, tungsten and tantalum were covered. Welding processes included gas, electric metallic arc, resistance, inert-gas shielded-arc, electron beam, dry box techniques, plasma procedures and ultrasonic applications as applied to joining of metals.

The final two lectures covered brazing processes of the above materials using nonferrous filler metals, such as alloys of copper, nickel, silver, tin and lead. Brazing of ferrous materials was also discussed.

Diplomas of attendance are being forwarded to all who attended the series of lectures. Many new members were attracted by the course.

MACHINES AND SUPPLIES

Springfield — Emil Steinert, manager of Westing-Arc Apparatus Engineering at Westinghouse Electric Corp., Buffalo, N. Y., spoke to 16 brave men who came out on a stormy night to the Oaks Inn, Springfield, Mass., for a regular meeting of the *Western Massachusetts* Section on March 14th. He chose for his subject "Welding Machines and Power Supplies."

His talk was very educational and was accompanied with slides and motion pictures. The movie was made at 7000 frames per minute.

For the past two years the section has invited a student from the Springfield Trade High School and a student from the Chicopee Vocational High School to attend as a guest. These meetings are very helpful to these boys.

TRAINING PANELISTS

Professor Roy McCauley of Ohio State talks while Dr. R. Dresher of the Detroit School Systems listens. Both participated in a training panel at the Detroit Section March 10th meeting

Each of these five panelists described their welding training programs, emphasizing the advantages and disadvantages of the over-all welding training system and possible corrections.

The meeting was further enhanced by the presence of four members of the national Educational Activities Committee, namely Morris Thomas, director of the Welding School of General Motors Institute; Roy McCauley; Les Wagner, chairman of Welding Section of College of Engineering at the University of Michigan; Carl H. Turnquist, divisional director of Vocational Education of Detroit Public Schools.

ARC WELDING METALLURGY

Saginaw—A joint meeting of the *Saginaw Valley* Section and the American Society for Metals was held on Thursday, March 2nd at the Hi-Life Inn with 80 members and guests of both societies present.

Program speaker was Dr. D. C. Smith of the Harnischfeger Corp., Milwaukee, Wis. His subject was on "Recent Trends in Arc Welding Metallurgy."

Dr. Smith reviewed the historical development of arc welding and covered electrodes for manual application. Included was a discussion of the properties of the newer types of electrodes and their application with particular emphasis on iron powdered basic low hydrogen types. Using slides, Dr. Smith showed how to overcome weld failures.

COVERED ELECTRODES

Grand Rapids—The February meeting of the *Western Michigan* Section was held at Duck's Restaurant on February 27th. Dinner preceded the meeting.

The talk at the technical session was given by E. H. Turnock of the Westinghouse Corp. in Montevello, Ala. The subject of his talk was "Stick Electrodes in Production and Special Steels," and was accompanied with slides. The speaker was very capable in presenting this timely subject, and much interest was shown in electrode selection.

Michigan

TRAINING FOR WELDING JOBS

Detroit—At their March 10th meeting, the *Detroit* Section participated in a very interesting and informative panel discussion on "Training for Welding Jobs," at the Engineering Society of Detroit.

A group of about 50 members and student guests enjoyed a very fine dinner. The coffee speaker was John Shouligian of the U. S. Department of Labor, who presented a very fine talk on "Manpower—Challenge of the 60's."

Following the dinner, the meeting adjourned to the auditorium for the panel discussion. A group of 130 of which about one-third were students enjoyed and participated in this discussion. The panel was composed of Roy McCauley, chairman of the Welding School, Ohio State University, representing the colleges and welding engineers.

Clifford Fulton, chief instructor of the welding school at Lincoln Electric Co., speaking for the technical institutes and the welding technicians, while Harry Saul, head of Welding Training at Detroit Cass Technical High School, and one of his students represented the high schools and welding operators. Furthermore, Oliver Coleman, head of Welding Training at Detroit's Trombley Trade School, with one of his students represented the trade schools. Dr. Richard Dresher of the Guidance and Counseling Department of the Detroit Public Schools, spoke on the guidance and counseling of welding students, and A. E. Lindsey of Dix Engineering Co., covered the employment of school trained welding personnel.

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PLAQUES FOR SPEAKERS

J. W. Kehoe (left) accepts plaque from S. L. Sullivan of the New Jersey Section. Mr. Kehoe participated in resistance welding seminar on February 16th

R. V. Thornton (left) presents speaker's plaque to D. C. Martin at the New Jersey Section February 21st meeting

Minnesota

AUTOMATIC WELDING

Minneapolis—On February 15th, the *Northwest* Section was treated to a highly informative and timely discussion on "New Applications of CO_2 Automatic Welding" presented by Floyd Addison of Westinghouse Electric Corp., Buffalo, N. Y.

The talk, which was given at the Elks Club, following the dinner meeting, was accompanied by a very interesting high-speed film of arc action resulting from shielding gas variations.

New Jersey

RESISTANCE WELDING SEMINAR

Newark—The *New Jersey* Section tried something new and unique at its regular monthly meeting held on Feb. 21, 1961, at the Essex House, Newark, N. J. Being conscious of its responsibility to all segments of the welding industry they are presenting a three-meeting seminar on resistance welding. This is being presented during the normal meeting period in a separate room. Its success was evidenced by an overflowing dinner crowd of more than 100 and a combined meeting attendance of 135.

D. C. Martin of Battelle Memorial Institute gave a very informative talk on "Methods for Testing Weldability of Steels." This was the speaker's second attempt to present this talk to the section, and it was a successful one. His first attempt in December ended in a "snowed-out" audience and had to be canceled. The section is grateful for his return visit.

J. W. Kehoe of Westinghouse Electric Corp. led off the resistance welding seminar with a talk on "Instrumentation for Resistance Welding." An attentive audience of 65 included groups from Ford Motor Co., Westinghouse, RCA, Falstrom Co., General Motors, Curtiss-Wright and many other organizations that find resistance welding a very important tool.

The two remaining topics to be presented at this seminar will be "'Hardware for Projection Resistance Welding" and "Resistance Welding Electrode Materials."

New Mexico

GAS SHIELDED-ARC PROCESSES

Albuquerque—The *Albuquerque* Section held its monthly meeting at the Desert Inn on March 9th.

Mr. Van Brown of the Linde Co., El Paso, Tex., was the speaker. He showed a film and slides on short arc welding. These films and slides were a "Preview of Modern Methods of Joining Metals." He also showed a film on powder lancing of heavy sections of concrete.

EDITORIAL "GOOF"

The April 1961 Welding Journal showed J. W. Flannery (left) and R. B. Thornton (center) presenting a UEC quota check for $1460 to National Secretery F. L. Plummer. Both are New Jersey Section members and not New York as erroneously reported

New York

LOW-TEMPERATURE EQUIPMENT

New York—One of the key problems facing industry today—that of designing low temperature equipment—was the subject for the February 14th meeting of the *New York* Section, held jointly with the

DOOR PRIZE AT A DINNER DANCE

F. Respiputo (left) accepts a first prize—a basket of "cheer"—from Dance Chairman G. Barrett at the annual dinner-dance which was held on January 27th by the Long Island Section

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GIFTS FOR TWO GUESTS

"Si" Greenberg (center) presents gifts to guest speakers, W. R. Apblett (left) and R. E. Hill. Mr. Apblett discussed the fabrication of equipment for cryogenic service, and Mr. Hill used liquid nitrogen at −320° F to demonstrate its use for the quick freezing of vegetables

THE TOPIC: HARD SURFACING

Guest speaker R. P. Culbertson (right) being congratulated by J. P. Broderick after his talk before the New York Section on March 14th

ASME. Technical Chairman "Si" Greenberg introduced the speaker, Foster Wheeler's chief metallurgist, William R. Apblett, who entitled his talk: "Designing and Fabricating Equipment for Cryogenic Service."

After defining the field of low temperatures and liquid gases, Mr. Apblett outlined the many problems associated with this type of service. Physical properties of various metals at temperatures below 0° F were discussed with the aid of charts which were slide projected. It was pointed out that the low-carbon steels were generally suitable for service down to −50° F. Temperatures approaching −150° F require the 3½% nickel steels with the fairly new 9% nickel steels being best for service down at −350° F.

AN EVENING BEGINS . . .

Northern New York Section members listen to Guest Speaker R. L. Peaslee as dinner meeting gets under way on March 2nd. Left to right are: J. Cuturilo, Mr. Peaslee, C. H. Kreischer and J. D. Carey

Properties of stainless steels vary as the temperature drops. Mr. Apblett projected several interesting data sheets comparing tensile strength, elongation and impact strength of the austenitic Type 304, and the relationship of the presence of delta ferrite according to the exact chemical composition. In the nonferrous field, information covering low temperature properties of aluminum alloys was given accentuating the aluminum-magnesium types which are considered superior for cryogenic work.

Mr. Apblett concluded his talk by citing several field applications wherein low temperature service was the prime consideration. These involved somewhat unusual joining problems requiring the welding of dissimilar metals for pressure vessels, chemical containers, etc. The usual question-and-answer session following the lecture was lively and informative.

The coffee talk preceding the technical session tied in nicely with the subject of low temperatures and liquid gases. A series of interesting demonstrations were conducted by Richard E. Hill, the local district manager of Air Products. Using several everyday objects as props, Mr. Hill demonstrated the effects of extreme low temperature by immersing fruits, vegetables, rubber tops and the like into liquid nitrogen for varying periods of time. Resultant embrittlement was obvious when these "frozen" articles were distributed to those in attendance.

HARD SURFACING

New York, N. Y.—A very interesting and little publicized technique of hard surfacing was the subject for the March Meeting of the *New York* Section held on March 14th at Victor's Restaurant. A large group of technicians and welders turned out to hear Russ P. Culbertson, Assistant Technical Director of the Haynes Stellite Co., speak on the "Application and Economics of Hardfacing."

Beginning with the mechanism of metallic weight loss, Culbertson categorized the different types of wear, listing specific field applications. It was pointed out that on-the-job service testing represented the best possible method of determining the suitability of a specific alloy to ward off attack. Although several proprietary laboratory devices have been constructed in an attempt to quantitatively evaluate individual overlays, field testing is still required.

Several general statements can be made, however. Nickel and cobalt

base alloys are best for oxidation and corrosion resistance. The cobalt base is usually considered superior to the nickel in resisting galling and for over-all service at elevated temperature.

Perhaps the most widely used surfacing alloys fall in the basic group containing less than 20% total alloying elements consisting mainly of C-Cr-Mo-Mn-Si. Such alloys are economical, easy to apply, perform well in service and have high cold hardness values. The most popular in this grouping is the 1%C–5%Cr–0.5%Mo which forms martensite upon cooling from welding temperatures. There are several modifications in the low alloy grouping each designed to accentuate specific properties.

Higher alloyed compositions offer greater general resistance to a variety of service conditions. A very popular composition in this category is the 2.75% C–27% Cr–0.65% Mn which is generally noted for its high cold hardness, oxidation resistance in the 800–1000° F range and general resistance to tempering.

Culbertson illustrated his talk with several excellent slides showing various tables related to wear properties. The effects of chromium in resisting oxidation as service temperature increases was noted as well as hot hardness and impact values.

The high chromium-nickel-manganese alloys are particularly suited for impact service. Such alloys offer as-deposited hardness values of RC28-35 work hardening to RC42-48. Composite deposite containing hard carbides entrapped within a soft steel matrix offer specific cutting properties in abrasive applications. Prior application of a low-alloyed 5% Cr – 0.80% Mo cushion will tend to minimize dilution when depositing these intermetallic compound overlays.

Following the meeting, the speaker elaborated on specific details during the usual question-and-answer session.

STAINLESS STEEL BRAZING

Albany—"Brazing the Stainless Steel for High-temperature Service," a subject of increasing interest to many industries, was thoroughly discussed by Robert Peaslee, vice president of the Wall Colmonoy Corp., Detroit, Mich., at the March 2nd meeting of the *Northern New York* Section, held at Hot Shoppes Inc., Albany.

Numerous brazing problems, pertaining to jet engine aircraft parts fabrication, were encountered prior to 1946 and the need for better brazing alloys became apparent. The work performed by his company in developing the necessary high-temperature alloys was emphasized during the discussion by use of slides showing engine parts which had been braze assembled followed by spin pit testing. These pictures revealed the high strength integrity of brazed joints in engine parts designed for brazing.

Mr. Peaslee explained the function of hydrogen and vacuum for providing protective atmospheres. The vapor pressure of various metal oxides was shown with respect to dew point of the protective atmosphere.

LARGE WELDMENTS FABRICATION

Olean — The *Olean - Bradford* Section met on February 21st for dinner and meeting at the Castle Restaurant in Olean, N. Y. The largest crowd of the season was on hand to hear John Latreyte Lang, welding engineer of the Lukenweld Div., Lukens Steel Co., Coatesville, Pa., lecture on large weldments fabrication. His talk was accompanied with slides covering the

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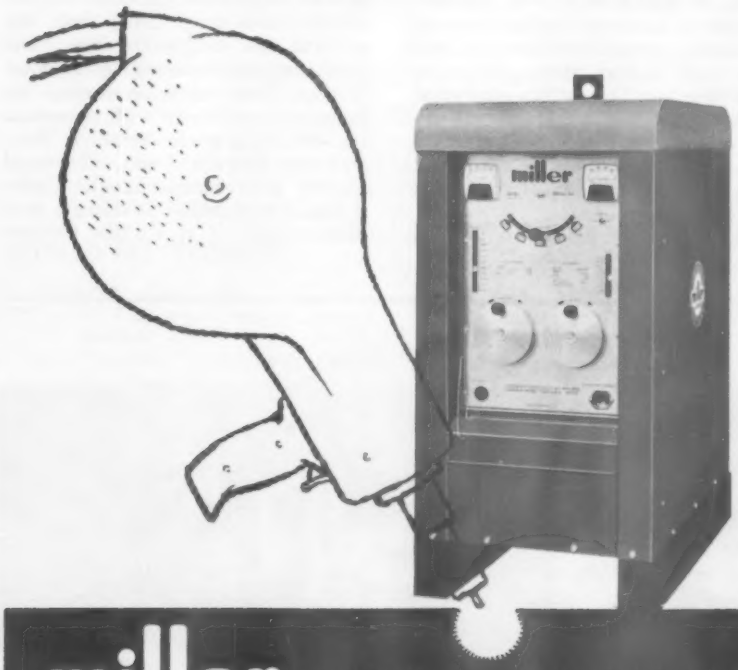

Swift and solid success of Miller's variable slope d-c constant potential 300 ampere welder and the 500 ampere CP-5 led to the development of the above 200 ampere version. Offered especially for use with recently introduced 200 ampere air-cooled guns having self-contained spools of wire, the CP-2 VS delivers:

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Information available upon request relating to 200 ampere CP-2 VS, 300 ampere CP-3 VS or 500 ampere horizontal model, the CP-5.

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"FOURTH ESTATE"...

Ted Jefferson, publisher of Welding Engineer, flanked by Bill Wolff (left) and Herb Owen of the Carolina Section where he spoke on February 13th

preparation, welding and handling of heavy weldments. The presentation was followed by a question-and-answer period.

North Carolina

FUTURE OF WELDING

Charlotte—The February 13th meeting of the *Carolina* Section was held in Charlotte, N. C. A tour was made of the Charlotte oxygen plant of National Welders Supply Co., Inc. The processing of air to produce oxygen, argon and nitrogen was shown.

Following the tour, a dinner meeting was held at the S&W Cafeteria with 52 members and guests present. The speaker at the technical session was T. B. (Ted) Jefferson, publisher of Welding Engineer Publications, Inc. The subject of his talk was "The Next Ten Years in Welding."

Mr. Jefferson predicted that the welding industry will be a two billion dollar industry by 1965 and double this by 1970. He pointed out that there are a number of major problems to be resolved. One of these is that the steel companies have not encouraged the use of welding in the construction of buildings and bridges but go along with rivets and bolts. With welding, it is estimated that a saving in steel tonnage of from 16 to 33% can be effected over conventional methods. Too many structural designers would rather pull out an old riveted design to adapt it to the new building or bridge than to design it anew. The information needed for welded design is NOW available.

Whether welding is a tool or a trade continues to be a stickler which may add to the cost of the welded job much the same as feather-bedding does in the operation of the railroads.

City fathers, legislators and code writing bodies need to know the importance and place of welding in modern industry.

Ohio

COST REDUCTION

Cleveland — The *Cleveland* Section staged the major social event of the year, a five session welding education course, and two technical meetings in addition to numerous committee meetings in a five week period during February and March. The events conducted at both the Manger Hotel and the Cleveland Engineering Center developed outstanding participation and demonstrated enthusiastic membership interest.

A Hawaiian motif on Ladies' Night attracted a crowd well in excess of 300 members, wives and guests. The event, chairmanned by Miss Janet Reed, centering around an evening of dancing and complete with traditional Hawaiian leis, punch and roast pig dinner, created a gay festive holiday atmosphere.

Following on the heels of this event was the annual education course. Theme of this year's program, organized by Paul L. Holden, was "Cost Reduction Through Welded Fabrication." Programmed to cover all phases of production, speakers and subject matter included Omer W. Blodgett, Lincoln Electric Co., "Designing for Function and Economy"; Gerald D. Ries and Henry Lipsey, Republic Steel Corp., "Relating Product Cost and Performance to Steel Selection"; Edward S. Young, Harris Calorific Co., "Capabilities and Limitations of Flame Cutting"; R. A. Wilson, Lincoln Electric Co., "Reducing Costs with Good Welding Techniques"; and David H. Hawes, Caterpillar Tractor Co., "Fixturing Profits into Your Welding."

The two technical sessions included a panel discussion on resistance welding chairmaned by David Adair, with Anthony Mellini, Babcock & Wilcox Co.; William Bacon, General Electric Co.; R. W. Dailey, Chrysler Corp.; and Jack Lott, North American Aviation, Inc., acting as panel members. The March technical session subject matter concerned acetylene vs. natural gas in gas cutting. The program, chairmanned by Edward Young, had users comment on personal experiences with respect to use of these gases for cutting. They included Darwin Dean, Cleveland Crane and Engineering; Glenn Johnson, Lewis Welding and Engineering; O. H. Kuhlke, General

HAWAII COMES TO CLEVELAND...

Cleveland Section members, wives and guests were greeted with leis on Ladies' Night in February. Miss Janet Reed, Ladies Night Chairman, is at the left

Acetylene vs. natural gas was the topic under discussion at the Cleveland Section March meeting. Panelists (left to right) for the evening were: seated—D. Dean and G. Johnson; standing—E. Young, O. H. Kuhlke and A. Rapp

METALLURGY LECTURER

J. E. Cleary was the lecturer at the opening session of the educational series being sponsored by the Mahoning Valley Section. Mr. Cleary (left) is shown immediately after being introduced on March 1st by Section Chairman R. Foxall (right)

American Transportation; and Alfred C. Rapp, Patterson-Leitch. These sessions were held at the Cleveland Engineering and Scientific Center.

POWER SOURCES

Columbus — The *Columbus* Section held its February 10th meeting at the Florentine Restaurant. Speaker at the technical meeting was G. K. Willecke, research director for Miller Electric Manufacturing Co. The subject of his talk was "Welding Power Sources." He discussed the development of a-c, d-c power units, compared motor generating power sources with the rectifier d-c source, and he emphasized the need to choose the correct power source for the particular type welding method and equipment to be used.

COATED ELECTRODES

Bucyrus—On Friday, March 10, 1961, the *Columbus* Section had a joint meeting with the North Central Section in Bucyrus, Ohio. Harry F. Reid, manager of technical service, McKay Co., York, Pa., was the technical speaker. His topic was "Progress in the Development of Coated Electrodes."

Mr. Reid introduced his talk by reviewing the different grades of manual electrodes that were in use prior to 1920 and the changes that have been made in the electrodes since then. New electrodes that have been developed since 1920 include the low hydrogen grades, the iron powder mild-steel electrodes and the iron powder low-hydrogen electrodes.

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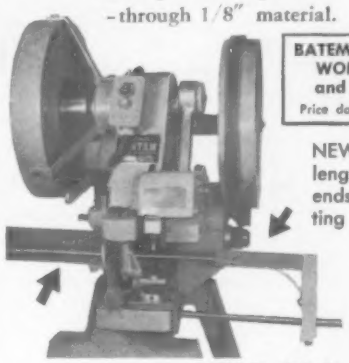

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After discussing the welding of stainless steel in general the speaker covered the development that has been made in the welding of "200" series alloys, the new chromium-nickel alloys, the precipitation hardening alloys and the vacuum-melt alloys. His concluding remarks covered the trends in hard surfacing.

EDUCATIONAL COURSE

Warren—The first session of the 1961 Educational Course of the *Mahoning Valley* Section was held at Harding High from 7 to 9 P.M. on Wednesday, March 1st. John E. Cleary, assistant chief metallurgist, Republic Steel Corp., Warren, Ohio, opened the educational series with a lecture on "Basic Metallurgy." Some 70 people from the Shenango Mahoning Valley were in attendance.

Mr. Cleary's lecture covered the blast furnace operation in the manufacture of iron. The refining of steel was described by explaining the operational functions of the open-hearth, electric furnace, bessemer converter and the oxygen converter. The solidification of the refined steel and the rolling of the ingot to a suitable product for fabrication used in welding was described in detail.

ELECTRON BEAM WELDING

Youngstown—The following reports of recent meetings of the *Mahoning Valley* Section have been received.

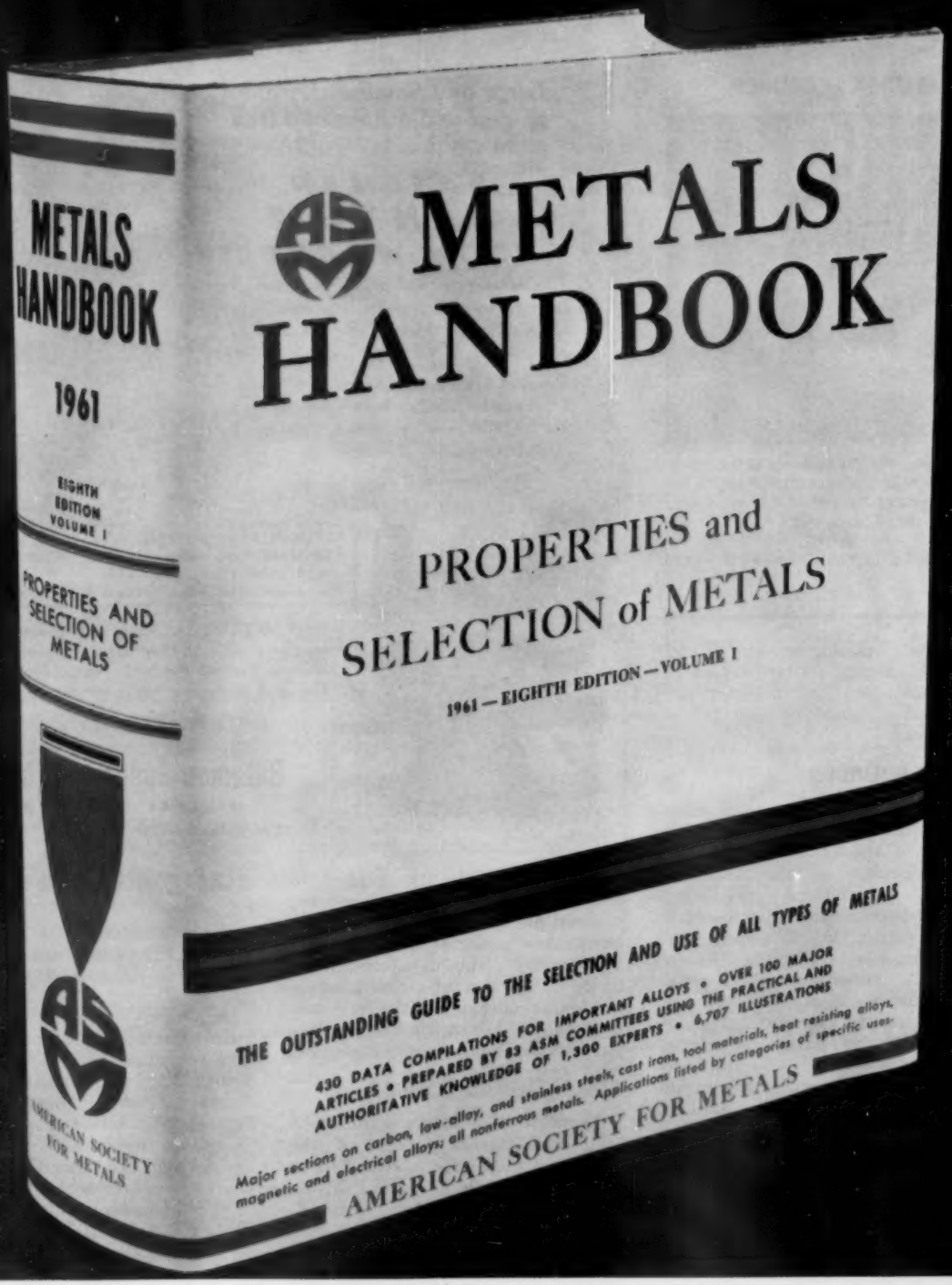
A highly technical talk on "Electron Beam Welding" was given by William J. Farrell of Sciaky Bros., Inc., Chicago, Ill., at the Sept. 15, 1960, dinner meeting. Although the talk was very technical in nature, everyone was interested in finding out about the actual working aspects of this technique.

H. Thomasson of the Canadian Westinghouse Co. was the speaker at the October 13th meeting. His subject was "Welding in Europe—Both East and West."

Mr. Thomasson used comparisons of Canada and the United States to compare the techniques used by East and West Berlin. His vast knowledge and experience in the welding field were very useful in elaborating on the techniques used in Europe. His talk was supplemented by three-dimensional slides.

On completion of the technical talk, members and guests stayed on to view some of Mr. Thomasson's personal slides and hear descriptive information on the various places he visited on his trip to Europe.

For details, circle No. 13 on Reader Information Card→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JOINT MEETING WITH ASCE

Section Chairman L. J. McGeady (right) with ASCE Section President W. N. Strobel (left) and E. Humphries who was guest speaker at the March 6th meeting of the Lehigh Valley Section

At the November 17th meeting, Robert Lachner of Robotron Corp., Detroit, Mich., discussed "Spike Power." The discussion covered the theory of spike power and the benefits and problems incurred in the use of this process. Many problems are still unanswered and still in the development stage since this is a relatively new process.

Pennsylvania

ALLOY STEEL

Allentown—The *Lehigh Valley* Section, at their dinner meeting on February 6th was honored by having the National President, R. D. Thomas, Jr., as the speaker for the Technical Session.

Mr. Thomas's subject was "Some Dramatic Applications of Stainless and Low-alloy Steel Welding." The speaker stated that stainless steel is a product which can readily be welded with high speed methods. He showed slides of several applications using stainless steel and various methods used in welding same. The second phase of Mr. Thomas's talk was welding in low-alloy steel field.

Art Phillips, Technical Chairman, spoke about his duties as a promotion man in the educational field of welding.

E. E. Goehringer, District Director, remarked about the work done in District Two.

Following dinner, George Allen, Advertising Dept., Bethlehem Steel Co., was the coffee speaker. The title of his talk was "So Let's Advertise."

PIPE FABRICATION

Allentown—On March 6th, the *Lehigh Valley* Section held its annual joint meeting with the Lehigh Valley Section of the American Society of Civil Engineers, at Walps Restaurant in Allentown, Pa., with W. N. Strabel, ASCE Section President presiding.

Following dinner, Wm. G. Rapp of the Bethlehem Steel Co. Fabricated Steel Construction Div., Bethlehem, Pa., showed color slides taken by him during a tour of the Scandinavian Countries and Holland. Mr. Rapp was a speaker at the Sixth Congress of the International Assn. for Bridge and Structural Engineering Held in Stockholm, Sweden.

The technical session speaker was Eric Humphries, Steelton Works, Bethlehem Steel Co., Steelton, Pa. Mr. Humphries' subject was "Fabrication of Expanded Line Pipe the Gas Industry." The speaker explained all the steps necessary to fabricate pipe from flate plate and showed slides of cutting and machining plate, forming and pressing the plate, welding of seams inside and out, cleaning, expansion of the pipe by water pressure, inspection, shipping and finally applications of pipe in the field. Following his talk, Mr. Humphries answered questions from the audience.

PLASMA ARC

Philadelphia—"Plasma Arc as a Metal Tool" was the subject at the February 20th technical meeting of the *Philadelphia* Section held at the Engineers Club. Gerald A. Jensen of the Research and Advanced Development Div., AVCO Corp., was the speaker.

Mr. Jensen opened his presentation with a 16-mm sound movie entitled "Arc Jet Application," covering the use of plasma generators as a space propulsion device and as a tool for materials testing.

He then described the use of plasma generators for spraying high melting point materials as protective coatings for resistance to wear, temperature corrosion and fabrication of materials such as tungsten. In addition, the use of muliple-circuit arc discharges for cutting and machining ferrous and nonferrous metals was discussed.

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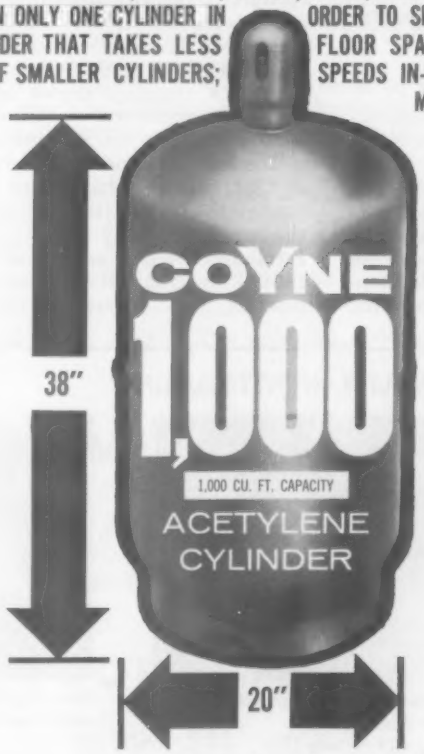

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INQUISITION IN CITY OF BROTHERLY LOVE

Guest speaker G. A. Jenson answers questions after the February 20th Philadelphia Section meeting where intense interest was expressed regarding the topic under discussion

Panelist W. Shuster responds to question from audience at Philadelphia Section March 3rd meeting. Left to right are: V. Nigrini, W. Shuster and W. Wooding

AUTOMATIC WELDING PANEL

Philadelphia — On Friday, March 3rd, another highly informative panel discussion was held by the *Philadelphia* Section.

"Automatic Welding" attracted approximately 75 interested members and guests.

William Shuster, welding engineer ACF Industries, Berwick, Pa., covered the growth and development of automatic welding and how it is applied at ACF.

Vic Nigrini showed a film of a huge hydro-press requiring weldments 15 in. deep using automatic processes.

One of the panelists was unable to attend. Walter Wooding of Arcos Corp. and Section chairman filled the gap by describing "Electroslag" welding.

STEEL MILL EQUIPMENT

Pittsburgh—On Wednesday, February 15th, 114 members of the *Pittsburgh* Section and their guests along with members of the Association of Iron and Steel Engineers Pittsburgh Section, were privileged to hear I. W. Evans, chief engineer in charge of Welding and Development for the Morgan Engineering Co., present a highly informative talk on "Welding Fabrication and Automatic Weld Surfacing." Mr. Evans described the conversion from castings to weldments that has taken place at Morgan Engineering and described the many applications of hard facing of steel mill equipment. Mr. Evan's talk was illustrated with many slides showing pictures of weldments in fabrication and hard surfacing equipment in operation.

LECTURE SERIES

Pittsburgh—The *Pittsburgh* Section presented its annual Lecture Series on March 7, 8, 14, 15, 1961. Guest speaker was Omer W. Blodgett, design consultant for the Lincoln Electric Co., Cleveland, Ohio. Mr. Blodgett's presentation, "Welded Structural Design," attracted a capacity crowd of 320 interested engineers, designers and technicians from the Tri-state Area.

The first three meetings were held in Clapp Hall, University of Pittsburgh, the fourth coinciding with the regular monthly meeting of the Pittsburgh Section at Mellon Institute. The subject for the fourth meeting was "Distortion—Causes and Control." The meeting was attended by many members of the Pittsburgh Sections as well as the people enrolled in the Lecture Series. The meeting was preceded by the monthly dinner at Webster Hall and followed by the regular coffee hour.

WELD HEAT-AFFECTED ZONES

Shickshinny—Dr. E. F. Nippes of the Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, was the technical speaker at the March 9th meeting of the *Susquehanna Valley* Section held at Foothills Manor. The title of his talk was "The Weld Heat-affected Zone."

Dr. Nippes restricted the scope of his address to the weld heat-affected zone of steels. He was concerned mainly with the prediction of weld heat-affected microstructure as developed on base metal bars subjected to thermal cycles precisely the same as thermal cycles produced under actual welding conditions.

Dr. Nippes stated that a large amount of research has been done in this area. However, results to date show that an ever-mounting quantity of research is required to

INFORMALITY AND FORMALITY IN PITTSBURGH

Guest speaker I. W. Evans (center) as he exchanged views with D. Marlin (left) and E. Cable during dinner at the Pittsburgh Section Meeting on February 15th

Part of audience which attended Pittsburgh Section educational series lecture on March 15th. O. W. Blodgett was the speaker

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We were all connected with a large nickel and nickel alloy producer. Our combined years of service total 78 years. This service was in production, quality control, metallurgy, technical and consultant services and sales of all welding electrodes and welding wires produced by this company. Further our knowledge of many metals and alloys and the welding of these is quite extensive.

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answer the problems which have appeared. The address was a highly technical nature and required an audience fully conversant with the terms and processes involved.

Texas

PIPE AND PRESSURE VESSELS

Beaumont—The following reports of meetings held by the *Sabine* Section have been received.

A discussion of the five basic causes of failures in pipe and pressure vessel materials was led by Helmut Thielsch of the Grinnell Co., Providence, R. I., at the Nov. 17, 1960, meeting held at the Flying Chief Restaurant.

R. A. Wilson, vice president of the Lincoln Electric Co., spoke on "The Rapidly Increasing Trend to Mechanization in Welding" at the Jan. 19, 1961 meeting.

Jack Goodford, chief welding engineer of Crucible Steel Co. of America, was the speaker at the February 16th meeting. He spoke on the "Welding of Stainless Steels."

STAINLESS STEELS

Houston—The guest speaker at the February meeting of the *Houston* Section was Jack A. Goodford, chief welding engineer for the Crucible Steel Co. of America, Pittsburgh, Pa. The subject on which he spoke was "Fabrication and Welding of Stainless Steels."

Mr. Goodford's talk was excellent, and during the two-hour presentation he covered many very interesting techniques and procedures in both fabrication and welding of stainless steels of various types.

The dinner and meeting were held in the dining and meeting room of the Houston Engineering and Scientific Society Building, and there were a total of 117 members and guests present for both.

DISTORTION

San Antonio—The *San Antonio* Section, was honored to have its District Director, Cliff Moss III, of Dallas, present for the March 6th meeting held at Capt. Jim's. Fifty-one members and guests attended the meeting with Fred W. Smith, chairman, presiding.

The program was a Panel Discussion on "The Control and Prevention of Distortion"; the panel consisted of Charles Brownrigg, E. E. Wagner and John E. Bergeron. Subjects were stainless steel exhaust assemblies for the aircraft industry, and structural framing members. These two subjects were discussed in terms of examples using the fundamentals of welding sequence, proper joint preparation, prebending, peening and the use of clamps. A question-and-answer period followed.

Utah

REFRACTORY METALS

Salt Lake City—The speaker at the February meeting of the *Salt Lake City* Section was Robert C. Bertossa, senior research metallurgist in charge of welding research for Pyromet Co., San Carlos, Calif. The subject of his talk was "Joining Research on High-temperature and Refractory Metals."

A social hour and dinner preceded the meeting.

ALLOY STEEL

Appleton—The *Fox Valley* Section held its February meeting on Friday, the 17th, at the Appleton, Wis., Elks Club.

The meeting was well attended with many members and guests turning out to hear President R. D. Thomas, Jr., and Secretary F. L. Plummer.

Prior to the regular meeting, 45 members attended a cocktail party and dinner in honor of our guests. The subject of Mr. Thomas' talk was entitled: "Some Dramatic Applications of Stainless and Low-alloy Steel Welding."

Wisconsin

NATIONAL OFFICERS' NIGHT

Janesville—President R. D. Thomas, Jr., and Secretary Fred L. Plummer were guest speakers at the Krane's Town and Country Club in Janesville, where the February 16th dinner meeting of the *Madison: Beloit* Section meeting was held.

Mr. Plummer, as coffee speaker, outlined the functions of headquarters and committees to the 78 members and guests present. He also described the new engineering center and the objectives of the International Institute of Welding. The Section's pledge in the amount of $400 toward the new engineering center was presented to Mr. Plummer.

Mr. Thomas gave a very enlightening presentation of "Some Dramatic Applications of Stainless and Alloy-steel Welding." Starting with a constitutional diagram for

GUESTS HONORED

Sharing the spotlight with National President R. D. Thomas, Jr., and National Secretary F. L. Plummer at the Fox Valley Section meeting on February 17th were: C. Mitchell, mayor of Appleton, Wis., and N. C. Miller, president of the Miller Electric Manufacturing Co. Surrounding Mr. Thomas from left to right are: Mayor Mitchell, Mr. Plummer, Mr. Miller and Section Chairman J. Teigen

NATIONAL OFFICER WITH FRIENDS

The Madison-Beloit Section was the scene for talks by National President R. D. Thomas, Jr., and National Secretary F. L. Plummer on February 16th. Left to right are: F. Theiler, K. Ellis, R. D. Thomas, Jr., C. Fenske, R. Graves and G. Duchon

stainless steel weld metal, he described their uses and the welding processes best suited to each case. He also stated that, since the United States has such a lead in the use of stainless and low-alloy electrodes, the European countries are looking to us for information.

A plant tour of the Fisher Body and General Motors plant in Janesville was made in the afternoon by 42 members and guests.

AUTOMATIC WELDING

Milwaukee—The *Milwaukee* Section held their regular monthly meeting on February 17th at the Ambassador Hotel.

The Honorable Mayor Maier, City of Milwaukee, was the coffee speaker. He discussed the problems that confront a mayor and the management of a city eleventh in population in the United States.

The high point of his talk covered the Urban Renewal Program.

The technical speaker was Jim Brown of the Allis-Chalmers Manufacturing Co. His subject was "Automatic Welding as a Tool of Production."

Mr. Brown gave an impressive talk which was amplified by very colorful slides of fixtures used for the welding of products used for earth moving equipment. He was very thorough in his discussion as to the use made of the fixtures and to their expectations in regard to the finished products.

He pointed out that in order to have a good finished product, the piece parts used in the assembly should meet with quality standards. Only when this is done is it possible to set up for automatic welding and maintain weld bead sizes without a rework.

From the slides it was apparent that this was being done, and also that a great deal of thought and effort had gone into the construction of the fixture in order to hold the pieces properly during the welding operation. It was also apparent that the fixture was made in such a way that a maximum amount of welding could be done in one setup.

Because of standard parts and maximum quantity runs, it was possible to make elaborate fixtures. Had the production been low it would have been very difficult to have justified the expenditure.

It was quite evident from the participation of the 207 members and guests attending the meeting that Mr. Brown had a very interesting subject.

EDUCATIONAL PROGRAM

Milwaukee—During the month of January, the *Milwaukee* Section held its annual educational program. Three lectures held at the Marquette University Science Building were well attended.

On January 9th, the first meeting of the series was conducted by D. C. Smith, chief metallurgist, Electrodes Div., Harnischfeger Corp. Mr. Smith's topic was "The Fundamentals of Welding Electrodes." On January 16th, Anton L. Schaeffler, chief metallurgist for the Welding Laboratory, Allis Chalmers Mfg. Co., was the speaker. His topic was "Basic Welding Metallurgy."

On January 23rd, Paul Ramsey, supervisor of the Welding Research Dept., A. O. Smith Corp., discussed the weldability of carbon and low-alloy steels. After Mr. Ramsey's talk, a panel discussion took place. Messrs. Smith, Schaeffler and Ramsey sat on the panel. An excellent job was done on answering the many questions put to the panel.

The educational program concluded on January 30th with a shop tour through the Allis Chalmers Mfg. Co. There were 225 people on this tour. They were split up in groups of 10 to 12 and conducted on a very informative trip. After the tour, everyone returned to the building from which they started and enjoyed a good visit over rolls and coffee.

DIGNITARIES

A pause in conversation with a guest speaker and the mayor of a major city at the Milwaukee Section February 17th meeting. Left to right are: Mayor Maier of Milwaukee, Section Chairman McKeighan, guest speaker J. D. Brown and Vice-chairman Smith

Authors . . .

please note!

All authors interested in presenting papers at the 43rd Annual Meeting to be held in Cleveland, Ohio, on April 9–13, 1962, are advised that the usual forms, "An Invitation to Authors" and "Author's Application Form," are printed as a detachable insert on pages 537 and 538 of this issue of the Welding Journal instead of being sent through the mail.

New Members

EFFECTIVE MARCH 1, 1961

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B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	203
Members	6,504
Associate Members	5,825
Students	340
Honorary Members	10
Life Members	31
Total	12,913

ALBUQUERQUE

Christopher, John A. (B)
Everett, Forrest G. (C)
Harber, Vade F. (B)
Rudd, Jerry W. (D)
Vishaway, Frederick H. (B)

ANTHONY WAYNE

Gensic, John H. (B)

BATON ROUGE

Atkinson, Edgar J. (B)
Kyzar, Wallace E. (B)

BOSTON

Catabia, Edward Joseph (B)
Hickman, Robert H. (C)
Lohnes, Ernest W. (C)
Martin, Thomas E. (B)
O'Brien, Hugh C. (C)
Oldford, Ernest R. (B)
Robertson, Herbert J. (C)
Zaffiro, Anthony N. (C)
Zona, Anthony (C)

CAROLINA

Carmean, E. R. (C)
Sult, Erroll C. (B)
Wagoner, James A. (C)

CHICAGO

Dorocke, Joseph M. (C)
Fleener, Dan (D)
Flood, Oscar W. (C)
Johnson, Donald R. (B)
Newnam, Walter G. (B)
Shida, Tomohiko (C)

CINCINNATI

Schneider, John (B)

CLEVELAND

Protiva, Richard F. (C)
Reed, Vince (B)

COLORADO

Dolinsek, Frank J. L. (B)
Zimmerman, Wm. G., II (C)

COLUMBUS

Lausten, Niel (C)
Norton, William C. (A)

DAYTON

Kampschaefer, Geo. E., Jr. (C)

DETROIT

Alff, Emil J. (C)
Arthur, Richard L. (C)
Ashman, R. G. (C)
Barber, Doyle G. (C)
Binswanger, William J. E. (C)
Black, James E., Jr. (C)
Blair, Eugene J. (C)
Braun, Arthur (C)
Caito, John (C)
Cazabon, George H. (C)
Clark, Archer D. (C)
Coon, Frederick M. (C)
Crandell, R. A. (C)
DeRoo, Frank G. (B)
Dopp, Robert F. (C)
Duncan, James W. (C)
Dziadzio, Leo (C)
Elliott, Max (C)
Eridon, John (C)
Feles, Paul (C)
Foley, Eugene P. (C)
Fonseth, Clancy A. (C)
Garner, Stanley J. (C)
Gelmine, Bert J. (C)
Goodis, James T. (C)
Gordon, Jacob F. (C)
Haggarty, Robert J. (C)
Hauser, Joseph J. (C)
Henderson, William J. (C)
Hilger, Fritz (C)
Holtzhouse, Irvin L., Jr. (C)
Hoppe, Charles W. (B)
Kine, Robert C. (C)
Kosnik, Bernard L. (C)
Krasinski, Chester (C)
Kraska, Ronald H. (B)
Kuron, Michael J. (C)
LaBarge, K. F. (C)
Lachowicz, Thomas A. (C)
Lohmolder, Elmer E. (B)
Magnan, Jean R. (C)
McCann, Raymond B. (C)
Menge, Conrad S. (C)
Menzie, Robert J. (C)
Mozal, Lawrence (C)
Paruch, Francis S. (C)
Phelps, Donald E. (C)
Poland, E. J. (C)
Quinlan, John (B)
Ragsdale, George G. (C)
Reed, Charles W. (C)
Reed, Thomas J. (C)
Roberts, Richard N. (C)
Rogala, Edward A. (C)
Shear, H. H. (C)
Sicklesteel, John Patrick (C)
Smith, Lawrence E. (C)
Smith, Warren L. (C)
Spitler, Clyde (C)
Stansell, William J., Jr. (C)
Stutzke, William G. (C)
Taylor, George E. (C)
Tyranski, Edward F. (C)
Vila, Martin R. (C)
Walker, Carroll W. (C)
Winsand, Amos (B)

INDIANA

Laakso, John H. (D)

IOWA

Alfred, Robert W. (B)
Gideon, James H., Jr. (B)
Johnson, Wayne J. (B)
Joline, Earl S. (B)
Rhoten, Ernest E. (B)

J. A. K.

Payne, Albert C. (C)
Sullivan, J. L. (B)

KANSAS CITY

Craig, Roger R. (B)

LEHIGH VALLEY

Duff, David H., Jr. (B)
Kurt, Ewald H. (C)
Mekeel, Van C., Jr. (C)
Newman, Clarence S. (B)
Resh, Elmer B. (C)
Spilman, Robert B. (C)
Wills, Wallis W. (B)

LONG BEACH

Wagester, Frank J. (B)

LONG ISLAND

Yoniak, Stanley (C)

LOS ANGELES

Eames, Frank (D)
Loeschmann, Martin W. (C)

LOUISVILLE

Chapman, F. L. (B)
Conyers, John D. (B)
Vowels, Freeman M. (B)

MADISON-BELOIT

Ayres, David H. (C)
Fisher, La Vern S. (C)
Mc Allen, Robert J. (C)
Molly, John E. (C)
Pospischil, Albert R. (C)

MAHONING VALLEY

Prevoznak, George (B)

MICHIANA

Schrader, Roland E. (C)

NASHVILLE

Hogue, Harold T. (B)
King, Wesley A. (B)
Olson, Norman J. (B)

NEBRASKA

Knox, Arthur L. (B)

NEW JERSEY

Douglas, Howard P. (C)
Harabin, Albert J. (B)
Milton, Charles B. (B)

NEW YORK

Cetra, Mauro A. (C)
Hollander, Milton B. (C)
Larson, Charles F. (C)
Mc Gee, Daniel M. (C)
Rapp, Robert E. (C)
Vecchio, Anthony J. (B)

NORTH TEXAS

Cox, Samuel L. (B)

NORTHEAST TENN.

Wilkinson, Ted (B)

NORTHERN NEW YORK

Bollinger, James F. (C)
Delmolino, Rino (C)
Jarvie, Alexander G. (B)
Levesque, Clarence W. (C)
Mahony, Robert P., Jr. (C)

NORTHWEST

Cremers, Thomas A. (C)

NORTHWESTERN PENNA.

Barson, Charles (B)
Davis, Edward H. (B)
Lamey, E. E. (B)

PHILADELPHIA

Elder, Roy, Jr. (B)
Pevar, Maxwell (B)
Rapp, William H. (C)

PITTSBURGH

Ecklesdafer, John G. (C)
Eller, James Nelson, Jr. (C)
Smith, Jack Wayne (C)
Yaniga, Albin J. (C)

PORTLAND

Kellersman, Bob (B)
Labs, David (C)
Swinford, Kenneth (C)

PROVIDENCE

Bane, Joseph P. (C)
Broslo, Arthur (C)
McGinn, Edward (C)
Vardner, Omer E. (C)

RICHMOND

Anderson, James O. (B)
Waddell, David L. (C)

SABINE

Lea, John A. (C)
Reaux, J. L. (B)

ST. LOUIS

Faith, William E. (B)
Schulze, Clifford L. (C)

SAN FRANCISCO

Janssen, Harvey (B)

SANTA CLARA VALLEY

Hage, Russell A. (B)
Hall, E. Gerald (B)
Kirkman, James C. (C)
Widstrand, Charles N. (A)

SOUTH FLORIDA

Dean, Harry D. (B)

STARK CENTRAL

Alt, George F. (C)
Bierwirth, Dale H. (C)

TOLEDO

Campbell, Del (B)
Kekes, Andrew Richard (C)

TULSA

Glenn, J. G. (C)
Moody, Darrell (B)
Reed, Harley M. (B)
Reynolds, Joe C. (B)

WESTERN MASS.

Cook, William H. (B)
Namislo, John W. (B)

WESTERN MICHIGAN

Muiderman, Anthony (C)

WORCESTER

Southard, Paul A. (B)

YORK-CENTRAL PA.

Gibson, R. J. (B)
Thompson, Donald L. (B)

MEMBERS NOT IN SECTIONS

Flores, Carlos Gonzalez (B)
Fuenmayor, Angel Emiro (B)
Kat, Dirk (C)
Moser, Jorge (B)
Portugal, Homobono Ehlers (B)
Rath, Robert (B)
Sallman, John B. (B)
Thouvenin, Louis Jean (B)
Yerrow, C. D. (B)

RECLASSIFICATIONS DURING MARCH, 1961

CHICAGO

Floyd, Columbus (B to A)
Hemenway, Henry H. (C to B)

PUGET SOUND

Maloney, Donald R. (D to C)

SAN ANTONIO

McKnight, Charles (C to B)

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NEWS of the industry

Gregory Headquarters Moved

Corporate headquarters of Gregory Industries, Inc., manufacturers of Nelson stud welding, stud driving and other construction fastening products with its principal plant in Lorain, Ohio, have been moved to the Libbey-Owens-Ford Building, 811 Madison Ave., Toledo, Ohio, according to George E. Gregory president.

The company's general offices remain in Lorrain and the move only involves a few persons.

Summer Welding Engineering Course

Ohio State's Dept. of Welding Engineering will present a Summer Conference Course in the fundamentals of Welding Engineering, June 12–23, 1961, in Columbus, Ohio.

The intensive two-week program is intended to help supply the educational needs of management, engineers, production supervisors and technicians employed in the application of welding. No specific prerequisite training or experience is required.

For further details contact William L. Green Dept. of Welding Engineering, 190 W. 19th Ave., Ohio State University, Columbus 10, Ohio.

Canadian Welding Convention

The National Convention of the Canadian Welding Society, May 9th, and 10th, 1961, will feature subjects of current interest to four segments of Canada's heavy manufacturing and construction industries.

The Convention is to be held at the Toronto Exhibition, Industries Building, concurrent with the National Industrial Production Welding Show. During the Show, some fifty prominent manufacturers of welding apparatus and supplies will be demonstrating the latest ideas to improve welding productivity.

The speakers program will cover welding in the nuclear component field, in the related area of boilers and pressure vessels, in the field of structural building, and welding in the basic steel industries.

On May 9th, a President's Banquet will be held at the Royal York Hotel and will be addressed by J. W. Kerr, president of the Canadian Electrical Manufacturers Assn., on the subject, "Public Image of Secondary Industries."

Information on the Canadian Welding Society Convention and Show may be obtained by writing to Convention Chairman, Canadian Welding Society, Room 421, 73 Adelaide St. W., Toronto.

Hartwick Open House

A two-day "open house" was held on March 16 and 17 by the Hartwick Welding Supply Co. to introduce its new, expanded facilities at 3700 Buchanan Ave., SW, Grand Rapids, Mich. Hartwick—formerly located at 670 Grandville Ave., SW—is the local Authorized Airco Distributor for Air Reduction Sales Co.

Welding Refresher Courses For Industrial Teachers

For industrial educators interested in brushing up on their welding techniques, the Hobart Welding School in Troy, Ohio, is offering its third annual one-week summer welding refresher course. The course will be held on the second and fourth weeks of June, July and August; the fee for the complete course is $20 with sleeping room available at $7.00 per week and meals available at the Hobart cafeteria at nominal cost.

In five full days of lecture, demonstrations and practice, such areas as welding machines, arc welding, welds and joints, vertical welding, sheet metal welds, welding cast iron, welding stainless steel, oxyacetylene welding, heliarc welding, etc., are covered.

All welding equipment and helmet are furnished, but the student must furnish his own work clothes.

For full details on preregistration, ask for Bulletin J-11280, Hobart Brothers Technical School, Troy, Ohio.

COMING EVENTS

A Calendar of Welding Activity

AFS

May 8–12. 1961 Castings Congress. San Francisco, Calif.

NWSA

May 8–10. Seventeenth Annual Convention. Hotel Commodore, New York, N. Y.

CWS

May 8–12. Canadian Welding Show. Toronto, Canada.

AIIE

May 11–13. 12th Annual National Conference and Convention. Sheraton-Cadillac Hotel, Detroit.

AWS

Sept. 25–28. 1961 National Fall Meeting. Dallas, Texas.

New Acetylene Plant

A new acetylene plant to supply Colorado Fuel & Iron Corp. is now under construction at Pueblo, Colo., by Linde Co., Div. of Union Carbide Corp. The plant will meet requirements of a contract just signed with CF&I for the supply of acetylene for a five year period.

The new plant will have a capacity of 1.5 million cubic feet per month of acetylene.

Bulk of the plant's supply will be piped throughout CF&I's Pueblo plant, where it will be used for welding, heating, scarfing and cutting operations. The plant will also supply acetylene to other industries in the Rocky Mountain area.

NEMA Plans First Western Conference

The National Electrical Manufacturers Association will hold its first Western Conference at The Biltmore Hotel, Los Angeles, Calif., June 8th and 9th, according to Joseph F. Miller, NEMA managing director.

Arrangements will be under the direction of Co-chairmen A. Arval Morris of Anaheim, Calif., president of Electra Motors, Inc., and Raymond M. Waggoner of Emeryville, Calif., vice president, West Coast, Hubbard and Co.

The Conference is planned primarily for member companies located in states west of the Rocky Mountains and for western representatives of members headquartered in other sections of the country. However, representatives of all member companies will be invited to attend and it is expected that many will be present from areas other than the Far West.

Preliminary plans call for starting the Conference with a luncheon on June 8th to which all sales allies of electrical manufacturers will be invited. Included will be electrical distributors, contractors, utilities, appliance dealers and other branches of the electrical industry. A top industry executive will keynote the Conference at luncheon at which A. D. R. Fraser, president of NEMA and president of Rome Cable Div., Aluminum Co. of America, will preside.

New Brazing Process

Using porous fiber metal mats, metallurgists at Armour Research Foundation have developed a new brazing process which will enable joints to be made in larger spacings.

The fiber metal mats are prepared by suspending short lengths of metal fibers in glycerin, then felting them to produce a porous body. They can be pressed, rolled, and sintered. The mats are infused with lower melting brazing filler metal, and are placed in the joint to be brazed, which is then heated above the melting point of the filler alloy.

The new process, developed on a project for the Association of American Railroads, is called fiber metal shim brazing. Production of the fiber metal mats is based on the Foundation's development of fiber metallurgy, a technique in which thin fibers of metal are interlocked like a felt cloth and bonded together with heat.

In addition to making joints in larger spacings, the process offers these advantages: wide variation in composition and properties, since both the fiber metal mat and the impregnating material can be controlled; greater mismatching of surfaces can be tolerated; applicable to refractory metals, such as tungsten and molybdenum, so as to provide joints of much higher remelt temperature than brazing temperature; ability to increase the filler metal viscosity where excessive fluidity causes difficulty; and greater strength of thick joints because of the reinforcement provided by the fibrous network.

T. W. Smith Moves

A tremendous growth in business, according to J. P. Ruddy, owner, has forced T. W. Smith Welding Supply Co. to relocate at 544 W. 53rd St., New York, N. Y. The new address provides 5500 sq ft of working area that includes a sales counter, sales office, accounting office, loading dock and storage areas for inventory, supplies, high-pressure and liquid cylinders, and delivery trucks.

Service Center Opened

Rolled Alloys, Inc., with service centers in Detroit, Mich., and South River, N. J., opened their third distribution center recently. The new address is 14044 Rosecrans, Sante Fe Springs, Los Angeles, Calif.

Paul Goetcheus, president of Rolled Alloys, Inc., has stated that Rolled Alloys future planning will take into account the diversification of heat resisting alloy end uses by geographic area.

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CLECOLOY

tubular tungsten carbide

Close Laboratory Control Insures High Quality

Clean CLEC-ITE particles (granular cast tungsten carbide) of controlled mesh sizes are used in CLECOLOY. Daily laboratory tests conducted by experienced technicians check the CLEC-ITE for micro-structure, grain size, carbon contents and non-metallic inclusions. Welding characteristics are checked daily.

Prior to rolling the tubes, the flux is thoroughly mixed with CLEC-ITE for uniform distribution of tungsten carbide. Accurate records are kept on each batch of fluxed material. Flux is prepared specifically for oxy-acetylene or atomic hydrogen methods of application.

For hard-surfacing applications specify CLECOLOY tubular tungsten carbide.

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ABS Elections

The 99th Annual Meeting of the Board of Managers and members of the American Bureau of Shipping was recently held in New York, N. Y., with the following individuals being re-elected as officers: David P. Brown as president, Lewis C. Host as senior vice president, Arthur R. Gatewood as vice president—engineering, K. Molter as treasurer and D. L. Parry as secretary.

Airco Oxygen Plant to Supply Blast Furnaces

Air Reduction Sales Co. recently announced the signing of a contract with Bethlehem Steel Co. for the construction and operation of a tonnage oxygen plant, the steel industry's largest single-column air separation facility, to supply Bethlehem Steel's blast furnaces at Johnstown, Pa.

Construction of the plant has begun and completion is scheduled for September 1961. With a production capacity of 675 tons of oxygen per day, the plant represents an investment in excess of 5 million dollars.

A pipeline will carry the oxygen to Bethlehem's ferromanganese blast furnaces. For emergency needs, facilities will be constructed for the storage of 400 tons of liquid oxygen and 8 tons of high-pressure gaseous oxygen. Air Reduction will own and operate the plant.

Semiconductor Inaugurates New Distributor Program

Inauguration of a new nationwide industrial distributor program for the Semi-conductor Div. of Syntron Co. has been announced by James I. Scott, sales manager.

Under the program, distribution of the Semiconductor Division's full line of certified, double-diffused silicon rectifiers will be made through qualified jobber distributors selected in all major domestic marketing areas. Jobber distributor appointments are underway, and are expected to be completed this month.

Scott said that factory inventory, jobber products and quantities, and other factors relating to the program were determined on the basis of surveys conducted among original equipment manufacturers, distributors and representatives.

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All you want— when you want it. In the RED DRUM. Wire for supplier...
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For details, circle No. 18 on Reader Information Card

New Research Organization

The formation of Materials Research Laboratory, Inc., a scientific research organization specializing in the solution of materials problems for industry and government, has been announced by Dr. E. J. Ripling, director of research. According to Dr. Ripling, the new organization is equipped to apply the latest concepts and techniques. Facilities include a complete metallographic and mechanical testing and evaluating laboratory, it is stated.

Areas in which this new research laboratory specializes include metal forming, evaluation of unusual mechanical and physical properties, as well as material selection and application, according to the announcement.

Metal & Thermit Appoints New Distributor

The appointment of Scranton Welding Supply Co., Scranton, Pa., to handle Metal & Thermit Corporation's Murex line of welding machines, electrodes and accessories has been announced by R. T. Brown, general manager of the company's Welding Products Division.

M&T's Murex line of welding machines includes: a-c arc welders for farm, medium-duty and heavy-duty industrial welding; combination a-c and a-c, d-c inert-arc machines; d-c rectifiers; high-frequency arc stabilizers; portable spot welders; engine driven welders; motor-generator welders; controlled arc power supply units; and special accessory equipment. The Murex line of electrodes includes more than 1000 types and sizes of mild steel, low alloy, stainless steel and special alloy electrodes.

Distributor Appointment

Rowell Welding Supply Co., 152 Charleston St., Mobile, Ala., has been appointed as an authorized distributor for Alloy Rods Company's complete line of electrodes and hard surfacing products according to E. R. Walsh, III, vice president of sales. Rowell Welding Supply Co. will cover Mobile and the surrounding marketing area.

Aluminum Association Elects Officers

John W. Douglas, President of Republic Foil, Inc., Danbury, Conn., was elected president of The Aluminum Association at its 75th annual meeting held recently. M. M. Anderson, an executive vice

For details, circle No. 19 on Reader Information Card →

World's champion corn picker welded with M&T Murex electrodes

In the past eight years, five championships have been won by farmers using the New Idea corn picker. It is also the world's biggest selling brand. For the kind of welds that contribute to championship performance year after year, the New Idea Division of Avco Distributing Corporation depends on M&T Murex electrodes—products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

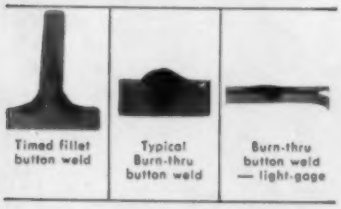
M&T MUREX
PRODUCTS FOR BETTER WELDING

C-OMANUAL button welding boosts output . . . cuts rejects

Here's one button the zipper hasn't replaced. In fact, this button process is the latest development in welding — a development that has replaced old-fashioned spot-resistance welding and riveting.

Armed with a lightweight hand gun using A. O. Smith's CO_2 C-OMANUAL process, the operator works from one side only. The button burns through to fasten steel up to 3/16 in the downhand position and 3/64 in the vertical. And welders take their helmets off to button welding — no need to wear one with this A. O. Smith process. Simple, too! Special operator training is not required. Just place the gun . . . pull the trigger! Hold until the welding stops *automatically*. Perfect button weld every time . . . no flux to clean.

Choice of nozzles permits welding of any of the standard joints (lap, fillet, butt).



Timed fillet button weld | Typical Burn-thru button weld | Burn-thru button weld — light-gage

Other button blessings include quality low-hydrogen weld metal, high deposition rates, full utilization of weld metal for low overall costs. Put this high-speed production tool to work for you. Send for Bulletin MW-253 for details.

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For details, circle No. 20 on Reader Information Card

president of Aluminum Company of America, who preceded Mr. Douglas as Association president, was elected chairman of the Board of Directors. Arthur V. Davis, a pioneer of the aluminum industry, was re-elected honorary chairman of the board.

Irving Lipkowitz, director of economic affairs, Reynolds Metals Co., New York, N. Y.; Louis Lippa, president of Apex Smelting Company, Chicago, Ill., and D. A. Rhoades, president of Kaiser Aluminum and Chemical Corp., Oakland, Calif., were elected directors-at-large for three-year terms. Two Association vice presidents were elected: Richard L. Allen, vice president, Bridgeport Brass Co., Bridgeport, Conn., and Mord Lewis, an executive vice president of Anaconda Aluminum Co., Louisville, Ky. N. H. Collisson, senior vice president, Olin Mathieson Chemical Corp., New York, N. Y., was re-elected a vice president.

Foote Mineral Names Agent

Ohio Ferro-Alloys Corp., Canton, Ohio has been named by Foote Mineral Co. as its U. S. agent for sale of electrolytic manganese metal to the foundry trade and to secondary brass and aluminum smelters. The move, according to Foote officials, is designed to provide improved service to less-than-carload consumers of electrolytic manganese metal.

Ohio Ferro-Alloys will stock Foote manganese at its various warehouse locations and will ship the material in split carload or truckload lots, thereby offering a saving to foundry users.

Product Line Discussed

A broad range of new electron tubes and semiconductors and the sales program for 1961 was presented to Amperex Electronic Corp. representatives at a Sales Meeting held in Providence, R. I., recently.

Technical briefing sessions were held, and a comprehensive tour of the recently-completed Amperex semiconductor plant in Slatersville, R. I., which is currently in mass production of Amperex Post Alloy Diffusion (PADT) transistors was conducted.

Corporations Settle Manufacturing Differences

Meehanite Metal Corp. and International Nickel Co., Inc., have concluded an agreement for the United States relating to the manufacture of magnesium bearing spheroidal graphite cast iron, according to Harry H. Kessler, president of Meehanite and Donald J. Reese of Inco's Ductile Iron Div. Under this agreement, the two companies have resolved their previous differences and the Meehanite Metal Corp. has acquired the right to grant sublicenses to foundries in the Meehanite group for the production of this metal under patents owned by Inco.

Castings produced under the sublicense agreements will be manufactured under the technical direction of the Meehanite Metal Corp. and will carry the Meehanite trademarks.

Airco Distributor Named

Air Reduction Sales Co. recently announced the appointment of District Oxygen Co., Inc., 3801 Bunker Hill Rd., Brentwood, Md., as its exclusive distributor in the Washington, D. C., metropolitan area.

Howard R. Montaigne, president and founder of District Oxygen Co., Inc., indicates that ground will be broken soon for a new, modern warehouse, store and repair station. Site of the new quarters will be situated on U. S. Route No. 1 in Bladensburg, Md.

ASME Aviation Conference

Aircraft and space ships that are faster, smoother, more reliable, safer and more economical were subjects discussed by a thousand engineers and aviation specialists at a meeting of the Aviation Division of The American Society of Mechanical Engineers who met recently in Los Angeles, Calif. Speakers and conference participants were in Los Angeles from all parts of the nation and from several countries.

Men who design, build and sometimes operate vehicles far above the surface of the earth have gathered here to exchange ideas and experience during the three-day conference. More than seventy talks, panel discussions and technical papers were presented during the three day meeting.

The Honorable W. B. Griffiths, of the British Ministry of Aviation, spoke on "England's Requirements Regarding Training and Safety of Aircraft."

Also among the highlights were a special pair of panel discussions at which experts from the United States and abroad discussed ways of training pilots better to reduce the possibility of disastrous errors in the operation of modern jets.

Looking further to the future,

For details, circle No. 21 on Reader Information Card→

World's most efficient power plant depends on M&T Murex electrodes

To get more electricity than ever from a ton of fuel, Philadelphia Electric's 325,000-kilowatt Eddystone No. 1 generating station superheats steam to 1200°F, 5000 psi pressure. No other power plant equipment handles steam at such high steam conditions. In welding most of the pipe for Eddystone, The M. W. Kellogg Company used Murex electrodes — products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

MUREX
PRODUCTS FOR BETTER WELDING

other specialists outlined latest thinking on how to air-condition housing projects on the moon to keep their human inhabitants from frying.

J. S. Smart, Jr., President Of AIME Metallurgical

J. S. Smart, Jr., of New York City, General Sales Manager, American Smelting and Refining Co., is 1961 President of The Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers.

After receiving his B.S. degree at the University of Michigan, Mr. Smart served with the Ford Motor Co. and later with the Detroit Lubricator Co. before joining Asarco in 1936 as a research metallurgist. He entered his present position in 1958.

ASM Realigns Staff

In a major realignment of its headquarters staff, American Society for Metals has appointed Ernest E. Thum, A. P. Ford and Albert L. Lloyd to positions as staff directors, according to Allan Ray Putnam, managing director of the Society. Thum will be director of editorial services; Ford, director of communications; and Lloyd, directo of administrative services and finance. Ted C. DuMond, whose appointment as director of chapter and member relations was announced previously, is now confirmed as one of the four key staff directors.

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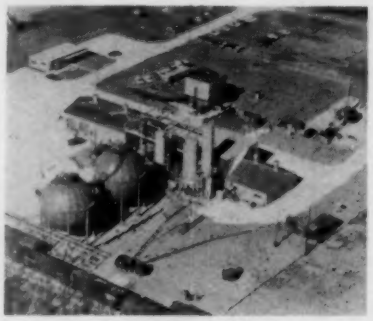
The need for expansion and growth of metalworking technology and productivity in the years immediately ahead, said Putnam, places a definite obligation on the Society to give industry every possible educational tool with which to meet its goals.

Liquid Oxygen-Nitrogen Plant in Operation

A new liquid oxygen-nitrogen plant in Neosho, Mo., built by Linde Co., Div. of Union Carbide Corp., is now in production supplying rocket engine development facilities at Fort Crowder Reservation. The new plant, with a capacity of 140 tons per day, will also supply the increased needs of other industrial gas consumers throughout the southwest by means of railroad



tank cars and highway liquid transports. The plant adds another vital link to Linde's nationwide chain of production facilities.

Neosho is the fourth of five Linde plants designed primarily to meet the growing needs of the nation's aerospace program. Two others producing liquid oxygen and nitrogen are in operation at Pittsburg, Calif., and at Huntsville, Ala. A third plant is currently producing 6.5 tons per day of liquid hydrogen rocket fuel at Torrance, Calif.; and construction of a 26-tons-per-day liquid hydrogen plant is scheduled to get under way at Fontana, Calif., this June, for completion in mid-1962.

Design Engineering Show, Conference

A substantially enlarged conference program and the largest exhibit ever held in the field will feature the 1961 Design Engineering Show and Conference. Both events will take place at the new Cobo Hall, Detroit, May 22–25.

Devoted entirely to research and development of new products, the twin events will present the latest developments in the materials and components which go into products, as well as design techniques which reduce production costs.

More than 400 companies will participate in the exposition. The machine design division of the American Society of Mechanical Engineers sponsors the conference. All available space in Cobo Hall will be used for exhibit booths.

Many of the discussions will deal with research on atomic and space subjects which have application in the field of consumer products. A major topic, discussed in several papers, will be reduction of production costs through use of automatic machinery and methods of designing products so that they achieve the economies possible through automation.

Visitors who wish conference information, rapid registration cards for the show and hotel information may write Clapp & Poliak, Inc., 341 Madison Ave., New York 17, N. Y.

ASTME Exposition

More than 6000 time saving, cost cutting products for use on American production lines will be shown at the American Society of Tool and Manufacturing Engineer's Tool Exposition at the New York Coliseum, May 22–26.

Most of these products are based on recent scientific advances. A parts cleaner designed for cleaning precision missile and electronic parts, for example, uses ultrasonic energy—silent sound—as a source of power.

Fully automatic machine controls and these, too, will be exhibited in abundance at the Exposition.

Other new items to be shown for the first time at the Tool Exposition include a high speed steel bonded titanium carbide for use as a cutting tool for chip removal operation on steel. A disintegrating machine used for removing broken taps, drills, reamers and other hardened tools from castings, dies, etc., and for piercing shaped holes in hardened dies without annealing and without distorting the castings or dies will also be shown.

Concurrent with the Exposition will be the Society's 29th Annual Engineering Conference at the Statler Hilton Hotel, which will feature plant tours, technical sessions, tech tours, a seminar, symposium, and public affairs panel.

Fifty papers ranging from welding, forging and cutting metals with explosives to new techniques in grinding will be presented during the conference.

For details, circle No. 23 on Reader Information Card→

World's largest single-engine crawler welded with M&T Murex electrodes

The giant Caterpillar D9 tractor is a mountain of earth-moving muscle with a pull of 67,190 lbs. Using its seven-roller tracks, the Cat crawler can claw into the earth, push huge boulders, maul tons of dirt. The average tractor is dwarfed by the size of this monster: 23 feet long and weighing over 75,000 pounds, with equipment. In building its D9 line of crawlers, Caterpillar Tractor Co. used Murex electrodes – products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

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PERSONNEL

Graver Names VP's

Two new vice presidents have been named by Clark Root, president of Graver Tank and Manufacturing Co., a division of Union Tank Car Co. Root also has announced the transfer of a third vice president.

Henry H. Hemenway [AWS] becomes vice president for research and engineering, and Lionel G. Lancaster becomes vice president for construction.

Willard M. Broxham, vice president for Eastern operations will take up new duties as vice president and Pacific Coast sales manager.

Hemenway, former director of research and development, is a graduate of the United States Naval Academy. He was with Foster-Wheeler for 23 years before joining Graver in June 1959.

Lancaster joined Graver as general manager of field erection in July 1959, after 20 years in the heavy construction field, with international experience in engineering, construction, contracting and management. He is a graduate civil engineer from the University of New Mexico.

H. H. Hemenway

Broxham's transfer, according to Root, will further implement Graver's program of expanded activities in the West.

Clarke Joins Arcos

Alfred Provencher, manager of the Arcos Corp. Chicago district office, recently announced the addition of Michael M. Clarke to his field staff.

Sylvania Parts Division Expands Sales Force

The Parts Division of Sylvania Electric Products, Inc., has expanded its field sales force by the appointments of a field sales manager, two district sales managers and one salesman, it was announced recently by Fred A. Martin, general marketing manager of the division. Sylvania is a subsidiary of General Telephone & Electronics Corp.

Appointed were: Joseph W. Parks, Jr., field sales manager; Wilson L. Bentz, district sales manager, Southeast; Richard S. Kelly, district sales manager, metropolitan New York; Richard A. Wilson, salesman, Indianapolis.

Casalis Selected

J. P. Casalis, Jr. [AWS] has been appointed district manager of the Air Reduction Sales Co. St. Louis district, it was announced by D. F. McCandlish, regional sales manager of Airco's midwestern region. As district manager, Mr. Casalis is responsible for the sale and distribution of all company products marketed through the district's facilities located at 630 S. Second St., St. Louis 2, Mo. Mr. Casalis succeeds W. M. Holley, who has resigned to become an Airco distributor for the St. Louis area.

A graduate of the Lincoln Technical Institute of Northeastern University, Mr. Casalis started with Airco in 1952 as a technical sales representative in the Boston district. In 1958 he transferred to the Philadelphia district and became assistant manager, distributor sales before receiving his present assignment.

Peterson Joins AVCO

The Avco Research and Advanced Development Division recently announced the appointment of J. David Peterson [AWS] as a senior engineer in the Industrial Products Subdivision in Wilmington, Mass. Mr. Peterson is a graduate of the General Motors Institute and was formerly a member of the General Motors manufacturing staff in Detroit. In his new position, Mr. Peterson will be associated with the design and development of a wide variety of plasma generator based tools for industrial use in manufacturing processes. The Avco PlasmaGun Spray Systems are the first of these new tools to be offered to industry.

Arcair Appoints Shryock

Donald E. Shryock has been appointed field representative for the Arcair Co. in the Mid-Western United States. His duties will include working with company distributors and a broad range of industries in that area. Mr. Shryock has, for a number of years, been closely associated with metalworking and the welding processes in their industrial applications.

Pullman-Standard Appointment

The appointment of B. H. Bradley as manager of works of Pullman-Standard's Hammond, Ind., plant was announced by Clyde B. Faverty, vice president in charge of manufacturing for the company. He succeeds B. J. Trautman, who is retiring after 46 years of service with Pullman. Faverty announced that Trautman will be retained as a special consultant to the manufacturing department.

Syntron Names Bigelow

Harold W. Bigelow has been appointed midwest district sales manager for the Semiconductor Div. of Syntron Co. and he will maintain headquarters in Chicago. He succeeds Homer E. Lytle, who has been named assistant sales manager —distributor marketing, with offices at Semiconductor Division headquarters in Homer City, Pa.

Mr. Bigelow will have responsibility for sales of Syntron Semiconductor Division products in Michigan, Wisconsin, Illinois, Missouri, Kansas, Nebraska, Iowa, Minnesota, North Dakota, South Dakota and Colorado.

Mr. Bigelow joins Syntron from the Westinghouse Electric Corp., Semiconductor Div., Youngwood, Pa., where he was an application engineer in the product planning department. He is a graduate of the University of Denver. Mr. Lytle has been with Syntron since 1942. He became a sales engineer in the Semiconductor Division in 1956, and had been midwest district sales manager since 1958.

Gencur Named Assistant Sales Manager

Andrew F. Gencur has been named Assistant Sales Manager—Finished Products Division of the Detroit Stamping Co., Detroit, Mich. In making the announcement, Harry C. Robeson, vice-president and assistant general manager, said that Gencur's "more than 30 years experience with De-Sta-Co, and his wide acquaintance in the field while a sales representative, fit him admirably for his new position."

Mr. Gencur joined the company in 1928. He progressed through various shop and production assignments to become foreman of the Finished Products Manufacturing Div., and, in 1945, was named a sales engineer of the division.

Sylvania Appoints Munkittrick

The Chemical & Metallurgical Div. of Sylvania Electric Products Inc., is expanding its field sales force in the metropolitan New York-New Jersey area by the appointment of Robert E. Munkittrick as a sales representative, it was announced recently by Byron L. Clark, field sales manager of the division. Sylvania is a subsidiary of General Telephone & Electronics Corp.

Munkittrick will make his headquarters in the Sylvania sales office, 1000 Huyler St., Teterboro, N. J.

Munkittrick joined Sylvania in 1951 and has served in various capacities in the manufacturing, engineering and marketing departments. For the past two years, he has been supervisor of sales correspondence for the division.

Evleth Retires

The retirement of Earl M. Evleth, Western Regional Manager for the RegO Plant Equipment Div. of The Bastian-Blessing Co., Chicago, Ill., was announced by R. H. Engstrom, vice president of RegO Sales. Having endeavored to retire from time to time, Mr. Evleth has repeatedly been persuaded by the company to remain active because of his unique value to the compressed gas industries.

Shortly after joining Bastian-Blessing as an engineer, in 1925, he designed the first portable pressure type automatic acetylene generator listed by Underwriters Laboratories, Inc. Since that time, other of his designs include the RegO GX and SX welding torches, KX cutting torch, KXA cutting attachment and the RegO Economizer which has saved users hundreds of thousands of dollars worth of oxygen and acetylene. As regional manager in the states of Arizona, California, Nevada, Oregon, Washington and western Idaho for the past ten years, Mr. Evleth has repeatedly contributed to the refinement of specialized regulating equipment.

Crucible Appoints Simpson Sales Director

Robert M. Simpson has been appointed Assistant Director of Sales of the Crucible Steel Co. of America. In his new position, Simpson will assist in the direction of all sales activity of the company and will act as second in command to Josef H. Buerger, Jr., Crucible's Director of Sales. His work will include supervision of both field sales, through the 38 branch warehouses and sales offices and the sales managers of product divisions.

In his previous assignment as Assistant General Manager—Field Sales, Simpson was instrumental in the expansion and improvement of Crucible's distribution system. Since 1957, when he was given this responsibility, Crucible branch warehouses have been added in six new cities, and ten facilities in other cities have been replaced with larger, modern warehouses.

Pullman Appoints Baker

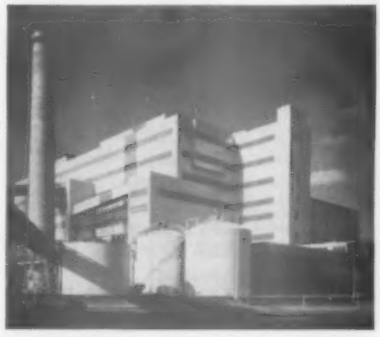
The appointment of R. R. Baker, New York City, as director of Pullman-Standard's newly-organized international sales department, has been announced by T. P. Gorter, vice president in charge of sales for the division of Pullman Inc.

Gorter, in announcing the appointment, said that Baker, who is now export sales manager, will be in charge of all international sales and licensing agreements for Pullman-Standard's line of railroad products.

Car-Mon Products Appoints Two

Bill Johnson and E. C. Sanford have been appointed as sales representatives for Car-Mon Products Co., Chicago manufacturer of carbon monoxide and welding fumes removal systems. Both men will handle the complete range of Car-Mon exhaust systems for garages, machines and welding shops, industrial and commercial construction, and many other applications where harmful gases must be removed.

Champion picker



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Bleeksma Named Vice President

Pieter van den Berg, chairman of the board of the North American Philips Co., Inc., has announced the appointment of Jan Bleeksma as vice president in charge of manufacturing of Amperex Electronic Corp., Hicksville, L. I., N. Y. Mr. Bleeksma's former position was plant manager.

McDermott Named to New Post

Appointment of Richard L. McDermott as manager of industrial sales was recently announced by Allis-Chalmers Norwood (Ohio) Works.

McDermott, who has been with Allis-Chalmers since 1951, had been manager of general industrial sales in the Cincinnati district since 1958. He was an application engineer in the electrical department at Norwood Works from 1953 to 1956 when he became a sales representative in the Cincinnati district.

McDermott is a graduate electrical engineer of Marquette University.

Graver Tank Names Three

The appointments of Alan Law and R. W. Briska to positions in the newly established Industrial Engineering Dept. of the Graver Tank & Mfg. Co., division of Union Tank Car Co., and the promotion of E. G. Vail to plant manager, Houston, Tex., have been announced by Clark Root, president of Graver.

Law will head the new department as chief industrial engineer. His previous position was that of plant manager at Houston, Tex. He originally joined Graver as an industrial engineer and now will report directly to Ivan Smith, East Chicago plant manager. Law is a graduate of the Illinois Institute of Technology.

The function of plant engineering will be incorporated with industrial engineering and will come under the direction of R. W. Briska, who has been appointed plant engineer. His group will report directly to Law.

Taking Law's place as the Houston, Tex., plant manager is E. G. Vail, now a resident of Tulsa, Okla.

Thermal Dynamics Names Two

Lawrence W. Scammon was recently appointed product manager for special equipment and processes at Thermal Dynamics Corp., Lebanon, N. H. He will head sales, product and field engineering in the areas of research equipment and plasma flame ultrahigh temperature equipment for specialized processes such as powder spheroidizing, materials testing and glass processing devices.

George A. Klasson has been named sales manager of plasma cutting devices, to handle sales of plasma flame metal cutting and welding equipment. He will also continue to supervise development and field engineering of the plasma flame cutter which cuts all types of ferrous and nonferrous metals.

Fisk Named Kenco Representative

Wesley F. Fisk, Jr., has been named regional sales representative in northern California, southern Oregon and western Nevada by Kenco Welding Supplies, Cupertino Calif.

Mr. Fisk will be responsible for sales, service and customer relations and will specialize in hardfacing materials. He was previously with California Welding Gases and the Auto Parts Co. in Salinas, Calif.

Browning Appointed

The appointment of Ross Browning as mid-western district sales manager was recently announced by the Vac-Hyd Processing Corp., Detroit, Mich.

A member of the Vac-Hyd organization for the past four years, Mr. Browning previously served the company in a technical capacity.

In his new position, Browning will represent Vac-Hyd in the states of Ohio, Pennsylvania and parts of Southern Michigan.

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Leading manufacturer of highly engineered metal working machines seeks outstanding man to direct all engineering functions. Must hold a degree in Mechanical Engineering or equivalent, and have a thorough design and related engineering background. Ability to administer a large department and lead people is essential. Location in large midwest city. This challenging position offers salary commensurate with opportunity. Reply in full, including earnings—all replies will be treated in strict confidence.

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Applicants should have experience in heavy fabrication with a good knowledge of metallurgy, being capable of developing techniques for the fabrication of alloy materials.

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Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D.C.

2,933,590—Stream Feeder and Method of Making Same—Nelson J. Leedy, Newark, and Robert G. Russell, Granville, Ohio, assignors to Owens-Corning Fiberglas Corp., a corporation of Delaware.

The present patent is on a method of securing tubular members formed of platinum in openings in a plate formed of platinum. The method includes inserting tubular members in the openings in the plate and engaging the current conducting support with such assembly. The current conducting electrode is moved into contact with a member and pressure is exerted on the electrode while electric current is flowed through the electrode, tubular member and plate for a regulated period of time to obtain the welding action. The pressure is maintained on the electrode for an interval after current flow is interrupted.

2,933,591—Offset-nozzle Torch—Thaddeus J. Wojciak, Elizabeth, and Peter R. Schaefer, Newark, N. J., assignors to Union Carbide Corp., a corporation of New York.

In this new gas shielded arc torch, a barrel is provided, and an electrode wire guide tube is eccentrically mounted in the barrel while a gas directing nozzle is mounted on the end of the barrel concentric with the guide tube but offset with respect to the barrel. A handle is secured to and extends laterally from the barrel and releasable means secure the barrel to the handle to permit rotary adjustment of the eccentricity of the nozzle.

2,933,592—Arc-welding Apparatus—Harry J. Bichsel, East Aurora, N. Y., assignor to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

In this patent, a relatively complex control circuit is provided for arc-welding apparatus for welding work with a consumable welding electrode. The controls operate the motor for feeding the electrode to the work and the controls include a tube, a capacitor and other members operating so that the weld arc is interrupted by a decrease in the speed of the motor prior to termination of predetermined weld intervals.

2,933,593 — Welding Method—Walter W. Edens, Wauwatosa, Willerd A. Schumbacker, West Allis, and Rushen A. Wilson, Wauwatosa, Wis., assignors to Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

The present patent is on a method of joining tubes of aluminum brass in tube sheets of Naval brass to form a joint of improved tightness and soundness. Initially an annular projection is provided on the tube sheets concentric with and in circumscribing relationship to each end of the tubes to form a vertical annular surface having a radial width substantially equal to the thickness of the tube and flush with the end of the tube. The tube ends and the projections are intimately fused together by a stable fusing arc energized by alternating current overridden by high frequency excitation.

2,933,594—Metals-joining Apparatus—Edwin W. Johnson, Forest Hills, Jujio R. Itoh, Wilkinsburg, and Robert L. Readal, Hampton Township, Allegheny County, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

A method of joining a first part of a refractory active electrically conducting material of the nature of titanium, zirconium, tungsten or the like to a second part is disclosed in the patent. A direct-current electric arc is produced to discharge to the surface to be joined of the first part and with the first part being a cathode at a pressure below the maximum pressure at which a discharge conducting the current to the discharge is to diffuse, and is positionally stable at the cathode to clean the surface. A brazing material is deposited on the clean surface which is then engaged with the surface of the second part, and the material and parts are heated to cause the material to join the parts.

2,934,632—Method of and Apparatus for Feeding Magnetic Welding Powder to Welding Wire—Hoyt H. Todd, Whittier, Calif., assignor to Western Carbide Corp., North Hollywood, Calif., a corporation of California.

Todd's patent relates to apparatus for supplying a stream of finely divided solid material to a dispensing zone for use in supplying welding powder to a welding wire. The apparatus includes a receptacle for the finely divided material and other means are provided to form a dispensing chamber that has a gaseous fluid inlet, a gaseous fluid outlet and a dispensing outlet at the desired dispensing zone. The apparatus functions to entrain the finely divided material for conveyance to the dispensing chamber by a carrier gas and with the dispensing chamber having a configuration for a 180 deg change in direction of the gaseous stream in the chamber so as to separate the finely divided material from the gaseous portion of the stream by inertia. Hence the material itself can move from the dispensing outlet of the dispensing chamber to be brought into association with a weld wire.

2,935,595—Stud-welding Apparatus—Douglas E. Bullis, Ilion, and Merle H. Walker, Mohawk, N. Y., assignors to Remington Arms Co., Inc., Bridgeport, Conn., a corporation of Delaware.

This new portable arc-welding tool for stud welding action, includes a stud-engaging chuck assembly movably mounted on a housing. A resilient means in the tool urge the movable assembly and chuck towards a work piece engaging position, and a manually adjustable means is present for varying the effective force of the resilient means to compensate for the effective gravity on the moving parts when operating the tool in various positions.

2,935,596—Fusing Machine—Earl A. Thompson, Ferndale, Mich.

Thompson's new fusing machine includes a pair of rotary turrets rotatable on spaced axes and in a tangential relation to each other. The turrets carry a plurality of die halves in their peripheries. Electric current supply means are connected to the turrets so that a fusing current may be applied to parts carried between the die halves and brought into engagement by the rotary turret members.

2,935,597 — Electrode Holder—Adolph B. Hugo, Mounds, Okla., assignor to American Steel & Pump Corp., Oklahoma Steel Castings Co. Div., Tulsa, Okla., a corporation of Delaware.

Hugo's new electrode holder includes a hollow tubular member adapted to receive and conduct electric current and compressed air therethrough. One air supply conduit communicates with the electrode mounting head positioned at one end of the tubular member so as to direct air along the electrode and toward the arc end thereof to displace molten metal therefrom.

2,936,229—Spray - weld Alloys—Arthur P Shepard, Flushing, N. Y., assignor to Metallizing Engineering Co., Inc., a corporation of New Jersey.

A novel composition of a spray-weldable, self-fluxing metal powder is disclosed in the present patent. This powder consists of a base metal selected from the group of nickel, cobalt and combinations thereof, and the powder contains boron as the self-fluxing element. The powder also contains about 0.2 to 5% by weight of aluminum.

2,936,361—Welding Apparatus—Stanley C. Shappell, West Boxford, Mass., assignor, by mesne assignments, to Sylvania Electric Products, Inc., Wilmington, Del., a corporation of Delaware.

A specialized apparatus for welding a lead-in wire to an electrical device to extend therefrom is disclosed. The lead-in wire connects to an electric contact member of a base and is positioned interiorly of the device. The apparatus includes electrode means for engaging the lead-in wire and for engaging the base so that when these members are brought into contact with each other, a circuit is closed and welding action of the lead-in wire to the contact member is effected.

2,936,362—Stud-welding System—Robert A. Brown, Milford, Charles S. Cummings, Easton, and Robert B. Hartman, Bridgeport, Conn., assignors to Remington Arms Co., Inc., Bridgeport, Conn., a corporation of Delaware.

An improved slag-forming fusible solid member for conducting current between a stud and a workpiece to initiate the arc and control the arc duration in a process for welding a stud to a work piece is disclosed in the above-identified patent. The member includes a relatively large vent means therein to provide for the free escape of heated gases and molten materials from the interior space of the member.

2,936,363—Apparatus and Method for Arc Welding—Robert A. Noland, Chicago, and Cecil C. Stone, Hinsdale, Ill. Assignors to the United States of America as represented by the United States Atomic Energy Commission.

This new arc-welding machine includes a magnetic cup having a central opening in its base. A magnetic core is positioned to extend from the central opening of the cup in alignment with but out of contact with the cup opening. The machine also has an annular welding electrode attached to one end of the core to the position in the central opening out of contact with the cup to extend no more than a small amount beyond the exterior of the base of the cup. A field coil surrounds the core and lies within the cup.

2,936,364—Metal-arc Working Process and Apparatus—George M. Skinner, Indianapolis, Ind., assignor to Union Carbide Corp., a corporation of New York.

Skinner has developed a new d-c welding and cutting apparatus wherein d-c welding power is connected between a consumable metal electrode and the work. The apparatus features use of a surge current condenser connected between the power supply leads for assisting starting of the arc between the electrode end and the work, and for stabilizing the arc.

2,936,365—Electric-welding Device—Francis J. Niemi, Gurnee, Ill.

The patented welding device is on an electrode holder for use in electric welding. A pistol-like housing is provided with a handle and a pair of gripping jaw means, one stationary and one movable jaw member making up the jaw means. Means are present to selectively operate the jaw means to move the movable jaw member towards and away from the stationary jaw to engage and/or discharge a welding rod electrode.

Current Welding LITERATURE

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

Stainless Steel

Investigation of Arc Welding of Heat Resisting Austenitic Steel, Grade E1572, V. A. Toropov. *Welding Production* (translation of Svarochnoe Proizvodstvo) (Sept. 1959), pp. 30–41.

Steel Corrosion

Corrosion Behavior of Welded Low Alloy Steel, D. C. Briggs, J. U. MacEwan and H. H. Yates. *Corrosion*, vol. 16, no. 4 (Apr. 1960), pp. 141–144.

Steel Metallography

Application of Electron Microscopy, I. Hrivnak. *Metal Treatment & Drop Forging*, vol. 27, no. 177 (June 1960), pp. 225–230.

Stress Relief

Medium Frequency Induction Heating Provides Precise Heat Control, Mobility for Stress Relieving, W. K. Haessler. *Welding Engr.*, vol. 45, no. 7 (July 1960), pp. 34–36.

Submerged-arc Welding

Submerged Arc Welding of Extension-Pieces to Fire Tubes, F. F. Benua. *Welding Production* (translation of Svarochnoe Proizvodstvo) (Oct. 1959), pp. 77–82.

Tanks

Aspects of Fabrication of Aluminum Vessels, A. R. Woodward. *Welding & Metal Fabrication*, vol. 28, no. 6 (June 1960), pp. 235–245.

Tantalum

Welding Tantalum for High-Temperature Systems, S. M. Silverstein, J. N. Antonevich, R. P. Sopher, P. J. Rieppel. *Metal Progress*, vol. 77, no. 6 (June 1960), pp. 103–109.

Testing

Investigation into Methods of Welding Tube Ends to Gussets, V. I. Novikov, V. A. Kovtunenko, O. I. Shumitskyi. *Engrs' Digest*, vol. 20, no. 10 (Oct. 1959), pp. 405–407.

Ultrasonic Weld Inspection—Status Report, J. E. Bobbin. *Nondestructive Testing*, vol. 18, no. 3 (May-June 1960), pp. 200–202.

Thermocouples

Method of Butt Welding Small Thermocouples 0.001 to 0.010 Inch in Diameter, C. M. Stover. *Rev. Sci. Instruments*, vol. 31, no. 6 (June 1960), pp. 605–608.

Titanium

Beta Titanium, E. F. Erbin. *Machine Design*, vol. 32, no. 13 (June 23, 1960), pp. 132–139.

Welding of Titanium and Titanium Alloys, G. E. Faulkner, C. B. Voldrich. *Battelle Memorial Inst.*—DMIC Report 122 (Dec 31, 1959), p. 66.

Tubes

Good Forming and Welding Procedures Make Precision Zircaloy Tubes, H. Meredith. *Am. Mach/Metalworking Mfg.*, vol. 104, no. 11 (May 30, 1960), pp 96–98.

Welded Tubes Slash Equipment Cost, E. W. Allardt. *Chem. Eng.*, vol. 67, no. 7 (Apr. 4, 1960), pp. 135–138.

Ultrasonic Welding

Ultrasonic Welder Design Considerations, W. Welkowitz. *Electronic Industries*, vol. 19, no. 5 (May 1960), pp. 106–109.

Ultrasonic Welding, *Mech. World*, vol. 139, no. 3484 (Nov 1959), pp. 464–465.

Ultrasonic Welding, B. E. Noltingk. *Welding & Metal Fabrication*, vol. 28, no. 7 (July 1960), pp. 260–266.

Welding Aluminum, Copper and Stainless Steel with Ultrasonics, J. B. Jones. *Metal Progress*, vol. 78, no. 1 (July 1960), pp. 117–120.

Uranium

Welding of Uranium, R. A. Noland, C. C. Stone. *U. S. Atomic Energy Commission—Tech. Information Service Extension* (TID-7562) (Jan. 1959), pp. 57–76.

Weldability

Study of Weldability of Heat Resisting 12% Chrome Steels, M. Kh. Shorshorov, V. V. Belov, V. N. Zemzin, I. D. Smirnova. *Welding Production* (translation of Svarochnoe Proizvodstvo) (Sept. 1959), pp. 17–29.

Weld Defects

Generalized Theory of Super-Solidus Cracking in Welds (and Castings), J. C. Borland. *Brit-Welding Jnl.*, vol. 7, no. 8 (Aug. 1960), pp. 508–512.

Note on Relationship Between Chemical Composition and Hot-Cracking in Mild and Alloy Steels, W. K. B. Marshall. *Brit. Welding Jnl.*, vol. 7, no. 7 (July 1960), pp. 451–453.

Problems with Restraint in Heavy Weldments. *Battelle Memorial Inst.—DMIC Memorandum 54* (Apr. 29, 1960), p. 6.

Weld Fatigue

Fatigue of Welded Structures. *Brit. Welding Jnl.*, vol. 7, no. 9 (Sept. 1960), pp. 577–587.

Influence of Residual Stresses on Fatigue Strength of Plates with Fillet Welded Attachments, T. R. Gurney. *Brit. Welding Jnl.*, vol. 7, no. 6 (June 1960), pp. 415–431.

Weld Properties

Relationship Between Microstructure and Mechanical Properties of Mild Steel Weld Deposits, K. J. Irvine, F. B. Pickering. *Brit. Welding Jnl.*, vol. 7, no. 5 (May 1960), pp. 353–364.

Weld Testing

Factors Which Affect Low-Alloy Weld-Metal Notch-Toughness, S. S. Sagan, H. C. Campbell. *Welding Research Council*—Bul. Series No. 59 (Apr. 1960), pp. 1–16.

Improving Method of Weld Radiography, L. A. Shehekin, A. P. Starostin. *Welding Production* (English translation of *Svarochnoe Proizvodstvo*) (Dec. 1959), pp. 91–94.

Recommended Practice for Radiographic Inspection of Fusion-Welded Joints. *Brit. Welding Jnl.*, vol. 7, no. 6 (June 1960), pp. 410–414.

Welding of Type 347 Stainless Steel, V. N. Krivobok. *U. S. Atomic Energy Commission*—Tech. Information Service Extension, TID-7562 (Jan. 1959), pp. 1–11.

Welding Education

How to Educate for Welding, R. B. McCauley, R. C. Wiley and J. H. Forrer. *Welding Engr.*, vol. 45, no. 8 (Aug. 1960), pp. 33–35.

Industry Lends Hand, Establishes College with Welding Engineer Course, M. D. Thomas. *Welding Engr.*, vol. 45, no. 8 (Aug. 1960), p. 39.

Manufacturer's School Provides Industry with All-Around Weldors, H. B. Carey. *Welding Engr.*, vol. 45, no. 8 (Aug. 1960), pp. 36, 38.

Welding Electrodes

Electrodes for Welding Type 347 Stainless, T. J. Moore. *Metal Progress*, vol. 78, no. 1 (July 1960), pp. 93–100, 162, 164, 166.

Welding Machines

Control of Spot Welders, J. L. Watts. *Mass Production*, vol. 36, no. 6 (June 1960), pp. 109–118.

Transistor NOR's Used in Spot-Welder Feedback Control, G. R. Archer, F. G. Dahlin. *Elec. Mfg.*, vol. 65, no. 2 (Feb. 1960), pp. 134–139.

New Fusion-Welder. *Aircraft Production*, vol. 22, no. 5 (May 1960), pp. 187–188.

Wire Products

Clamping Springs for 1400° Brazing. *Wire & Wire Products*, vol. 35, no. 5 May 1960), pp. 612, 657.

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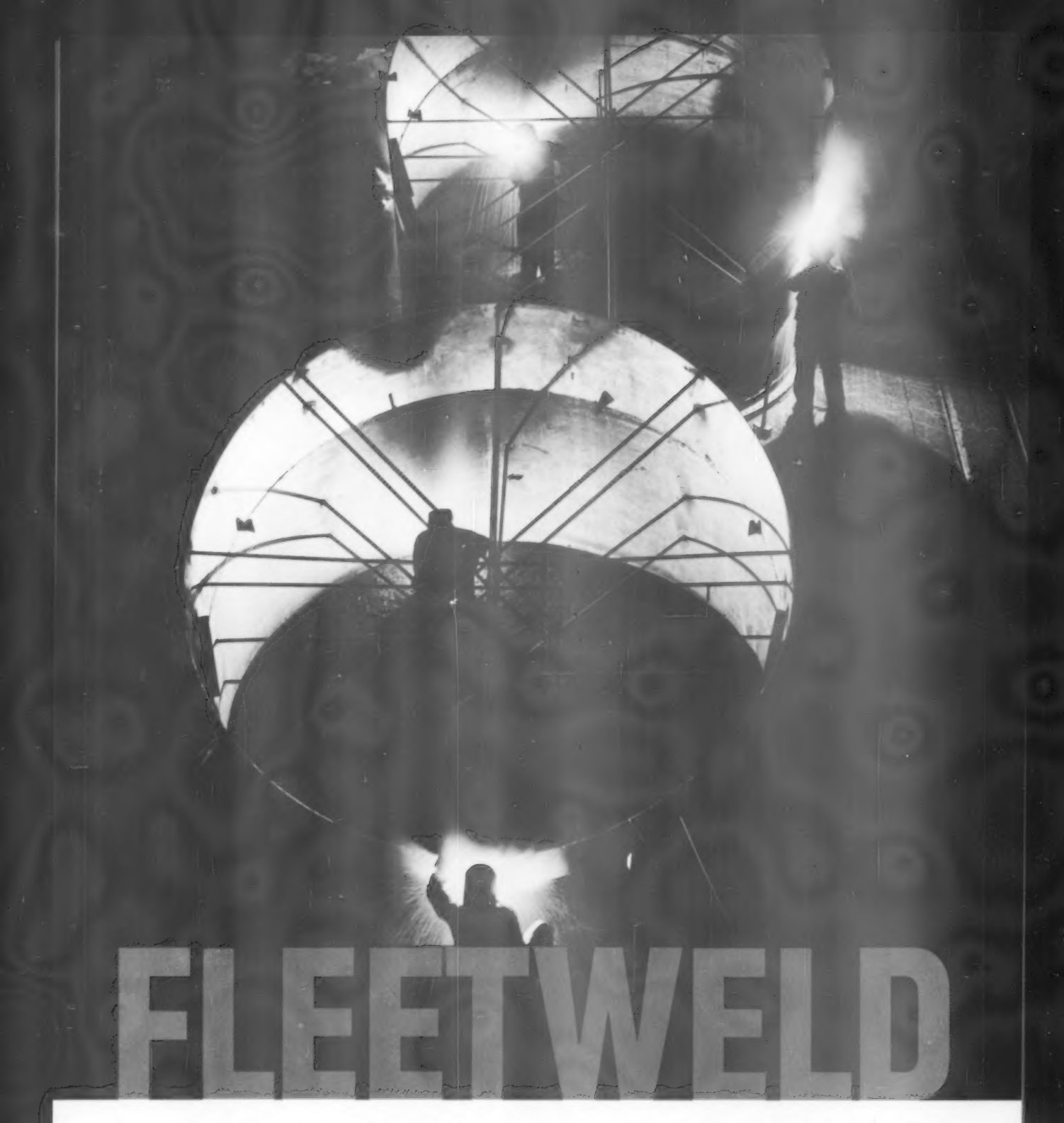
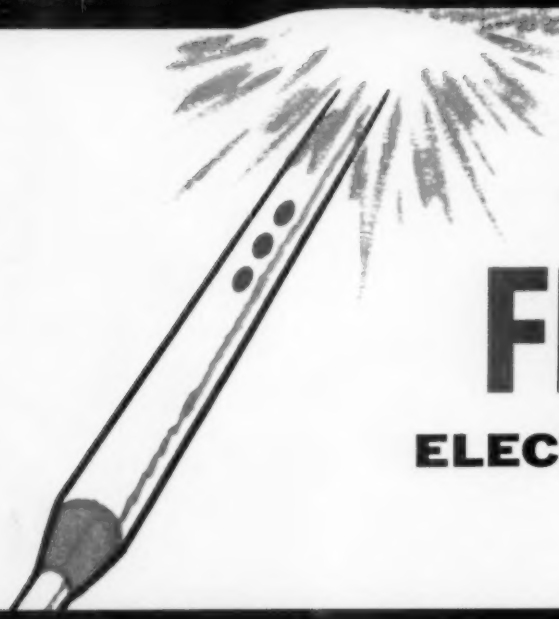


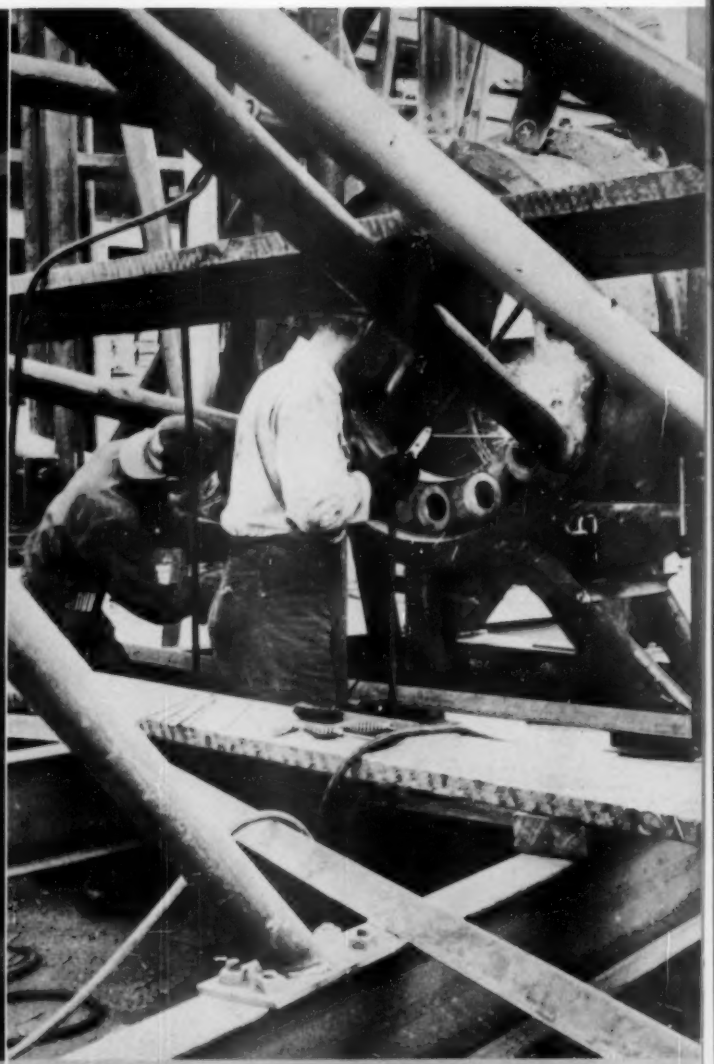
FLEETWELD

Several companies make welding electrodes. Many of them are good. But, ask a weldor which one is best for all-position welding, which one welds best on rusty, oily plate, which one delivers best all-around performance. Chances are, he'll say Lincoln Fleetweld 5. Though Fleetweld 5 is the standard of the industry, it's only one of a family of Lincoln electrodes—each one made for a specific mild steel welding task. Read about them all inside.



THESE ARE LINCOLN
FLEETWELD
ELECTRODES ON THE JOB

Customer selected Fleetweld 37 to weld this blower fan housing. Good choice. For, its soft arc and fine ability to weld all position, Fleetweld 37 is widely used on sheet metal work where ease of operation and good appearance are essential. Fleetweld 47 is used in flat or near-flat position.



To get extra tensile strength, Shield-Arc 85 is used on this tubular truss complex. Tube ends chamfered for good metal penetration. Widely used in pressure pipelines and piping due to its high strength. Shield-Arc 85P, similar to 85, makes pinhole-free cover pass welds.

It is true that Fleetweld 5 is probably the most famous electrode in the welding industry. And for this, we are grateful.

But did you know that there are several other Lincoln electrodes—all variations of Fleetweld 5—that have been developed primarily to suit some particular customer need? For instance, when the petroleum industry told us they wanted a smooth-working E6010 rod to give the finest X-ray quality possible on stringer beads, we developed Fleetweld 5P. And for those who use AC machines, we developed Fleetweld 35 which is identical to 5 in every other respect. Fleetweld 180 was expressly developed for AC machines having normally lower open-circuit voltages than industrial machines.

To provide an E7010 version of Fleetweld 5, with proportionately greater tensile strengths, Lincoln engineers came up with Shield-Arc 85. And, Shield-Arc 85P was developed to assure beautiful cover passes without pinholes.

While Fleetweld 5 is the best known E6010 electrode, Fleetweld 7 is the most widely used E6012 electrode for all-position welding. For those customers who wanted a really high-speed E6012 electrode, 7MP was introduced. Coating has an iron powder content which adds to its arc speed and deposition rate.

Some lap and fillet welding is extremely high production work. Here, Fleetweld 72 shines. In fact, all three of these 6012 electrodes—7, 7MP and 72—are excellent for production welding where there is poor fit-up or where work is out-of-position.

Some customers who fabricate much sheet metal work in all positions desired still easier operation and good appearance. For them, we developed Fleetweld 37. And for those who wanted high speeds and deposition rates in flat or near-flat position, there is Fleetweld 47.

So, there they are, the entire Fleetweld family: 5, 5P, 35, 180, Shield-Arc 85 and 85P, Fleetweld 7, 7MP, 72, 37 and 47. Each—born of a specific need—does its job particularly well. Want help selecting the best Fleetweld electrode to suit your problem? See special offer, next page.

LINCOLN ELECTRODES

Here, Fleetweld 7 is used to weld railroad car sections. Picked because of its ability to bridge gaps. Fleetweld 7 and 7MP (a metal-powder rod), are well suited to welding downhill applications, joints with poor fit-up. Perfect for high-speed fillet and lap welding.

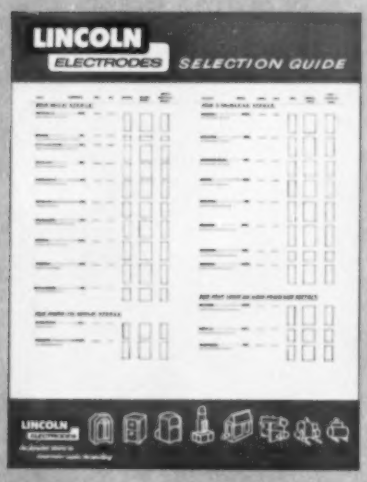
Fleetweld 5 is an industry standard for pipe welding and general maintenance work since it is an all-position electrode. Fleetweld 5P was specially developed to permit smooth pipeline stringer bead welds and deliver X-ray quality superior even to that which you get with Fleetweld 5.

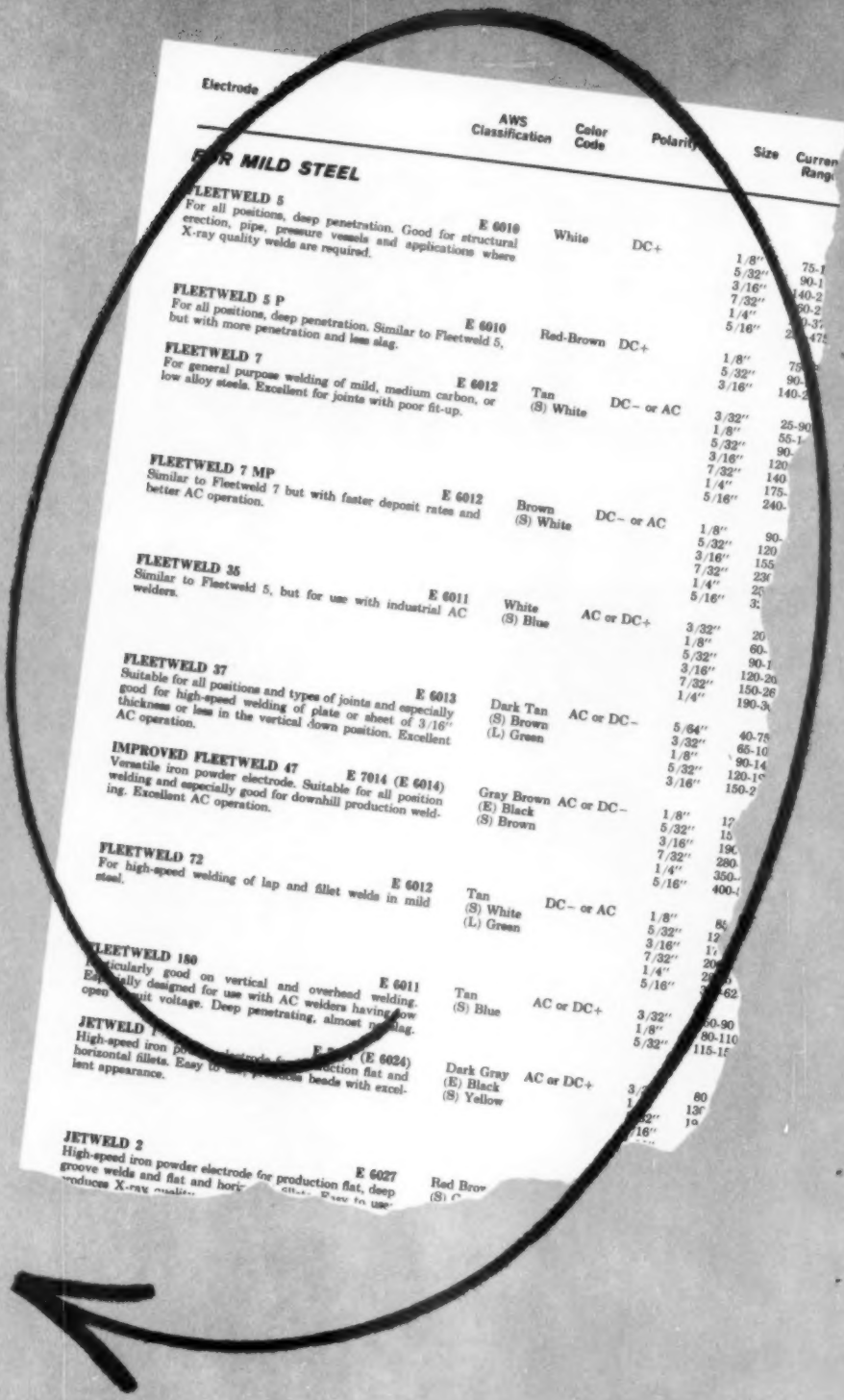
NEW LINCOLN ELECTRODE SELECTION GUIDE AVAILABLE... ABSOLUTELY FREE!

This big, new electrode wall chart lists all Lincoln electrodes made. With it, you can select the exact electrode for your application. What's more, there are columns which list "benchmark" current ranges which will help guide you to the proper setting of your machine for each type of job, each type electrode.

On this chart you'll find sections dealing not only with mild-steel electrodes but hard-to-weld steels, cast iron, low-alloy and high-tensile steel electrodes, etc. In addition to specific electrode recommendations, each is identified by AWS color code markings.

We believe this chart will help you make better electrode selections, save you money. Why not order your copy today? It's free of charge. Write The Lincoln Electric Company, Dept. WW-11, Cleveland 17, Ohio.




Electrode
AWS Classification
Color Code
Polarity
Size
Current Range
FOR MILD STEEL
FLEETWELD 5
For all positions, deep penetration. Good for structural erection, pipe, pressure vessels and applications where X-ray quality welds are required.
E 6010
White
DC+
1/8" 5/32" 3/16" 7/32" 1/4" 5/16"
75-1 90-1 140-2 160-2 0-37 2 475
FLEETWELD 5 P
For all positions, deep penetration. Similar to Fleetweld 5, but with more penetration and less slag.
E 6010
Red-Brown
DC+
FLEETWELD 7
For general purpose welding of mild, medium carbon, or low alloy steels. Excellent for joints with poor fit-up.
E 6012
Tan (S) White
DC− or AC
1/8" 5/32" 3/16"
3/32" 1/8" 5/32" 3/16" 7/32" 1/4" 5/16"
25-90 55-1 90- 120 140 175- 240-
FLEETWELD 7 MP
Similar to Fleetweld 7 but with faster deposit rates and better AC operation.
E 6012
Brown (S) White
DC− or AC
1/8" 5/32" 3/16" 7/32" 1/4" 5/16"
90- 120 155 23(2(3:
FLEETWELD 35
Similar to Fleetweld 5, but for use with industrial AC welders.
E 6011
White (S) Blue
AC or DC+
3/32" 1/8" 5/32" 3/16" 7/32" 1/4"
20 60- 90-1 120-20 150-26 190-3
FLEETWELD 37
Suitable for all positions and types of joints and especially good for high-speed welding of plate or sheet of 3/16" thickness or less in the vertical down position. Excellent AC operation.
E 6013
Dark Tan (S) Brown (L) Green
AC or DC−
5/64" 3/32" 1/8" 5/32" 3/16"
40-75 65-10 90-14 120-1 150-2
IMPROVED FLEETWELD 47
Versatile iron powder electrode. Suitable for all position welding and especially good for downhill production welding. Excellent AC operation.
E 7014 (E 6014)
Gray Brown (E) Black (S) Brown
AC or DC−
1/8" 5/32" 3/16" 7/32" 1/4" 5/16"
12 15 19(280- 350- 400-
FLEETWELD 72
For high-speed welding of lap and fillet welds in mild steel.
E 6012
Tan (S) White (L) Green
DC− or AC
1/8" 5/32" 3/16" 7/32" 1/4" 5/16"
8 12 1 20 2 3 62
FLEETWELD 180
Particularly good on vertical and overhead welding. Especially designed for use with AC welders having low open circuit voltage. Deep penetrating, almost no slag.
E 6011
Tan (S) Blue
AC or DC+
3/32" 1/8" 5/32"
50-90 80-110 115-15
JETWELD
High-speed iron powder electrode for production flat and horizontal fillets. Easy to use, produces beads with excellent appearance.
E (E 6024)
Dark Gray (E) Black (S) Yellow
AC or DC+
80 13(1
JETWELD 2
High-speed iron powder electrode for production flat, deep groove welds and flat and horizontal fillets. Easy to use; produces X-ray quality
E 6027
Red Brow (S) C

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LINCOLN ELECTRODES

New Literature

Metals Handbook Description

A 32-page illustrated brochure has been issued by American Society for Metals, Novelty, Ohio, to describe the content of its new *Metals Handbook*, 8th Ed., Vol. 1, "Properties and Selection of Metals." The brochure includes actual examples from each of the Handbook's major sections, with information on how the book was compiled by 1335 metalworking experts in association with 83 author committees representing every area of industry.

Four years in preparation, the new 1300 page ASM Metals Handbook represents two and a half times as much information on properties and selection of metals as in the last edition. Major sections include Carbon and Low-Alloy Steels, Cast Irons, Stainless Steels and Heat Resisting Alloys, Tool Materials, Nonferrous Metals, and special features on magnetic, electrical and other special purpose materials, a dictionary of technical definitions and special indexes.

For your free copy, circle No. 51 on Reader Information Card.

D-C Welding Machine

The "Sureweld" DRCP-33 welder which offers continuous voltage and slope adjustment and is especially adapted to critical welding jobs on lightgage metal is described in a new bulletin available from the National Cylinder Gas Div. of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

The constant-potential d-c welding unit has a range of 10 to 40 welding volts and is designed for the inert-gas metal-arc welding process. The bulletin lists features of the machine and describes its capabilities. A specification table gives current, capacities and dimensions.

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Metal Cleaning Bibliographical Supplement

The 1960 Supplement to the Metal Cleaning Bibliographical Abstracts, STP 90-E, covers the period 1958 through early 1960. There are 114 references for this period as well as 100 newly added references for the period prior to 1958.

New metals present new cleaning problems which must be solved by advanced techniques or combinations of older methods. Ultrasonic cleaning, in-place cleaning of equipment in plants, or of pipe lines, and the cleaning of electronic components are receiving much consideration for the special problems involved. The reader will find not only references of practical application but also theory and laboratory evaluation.

Copies of this book may be obtained from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., at $2 each.

Welding Accessories

A sixteen-page catalog describing welding accessories and safety equipment is being offered by Jackson Products, Air Reduction Sales Co., Warren, Mich. Arc welding electrode holders, ground clamps, cable connectors, etc., and head and face protection devices such as safety hats and caps, welding helmets, goggles, and face shields are pictured and described.

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Russian Translation on Diffuse Coatings on Iron and Steel

The diffusion process of applying successive layers of various protective metal coatings is considered by a Russian metallurgical authority, N. S. Gorbunov, as the most promising solution to the problem of protecting iron and steel surfaces from oxidation at high temperatures, according to a recently translated study on diffuse coatings on iron and steel published by the Academy of Sciences of the USSR. This successive-layer multicomponent coating technique is reported to be more effective than the simultaneous application of a single multicomponent coating mixture of protective metals.

Entitled *Diffuse Coatings on Iron and Steel*, the book is available from the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce, Washington 25, D. C., at a cost of $1.75.

Metals Joining Bulletin

A new bulletin (No. 84) discussing the solution of metals joining problems by brazing is available from Handy and Harman, 82 Fulton St., New York 38, N. Y.

This bulletin contains illustrated success stories about brazing of parts, components and products. Some involve similar metals and dissimilar metals.

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Vacuum Components

A condensed catalog of high vacuum components and equipment manufactured by NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass., is now available through the firm and its regional sales offices.

The 8-page catalog summarizes the complete NRC line of high vacuum mechanical and diffusion pumps, valves, gages, accessories, portable pumping systems, coaters, furnaces, electron beam welders, altitude chambers and freeze drying equipment.

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Gas Cutting Machines

American Messer, Cutting Machines Div., 405 Lexington Ave., New York, N. Y., has available copies of a reprint article, "Modern Heavy-Duty Gas Cutting Machines," recently published in the British *Welding and Metal Fabrication* magazine.

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Silicon Rectifiers

A new bulletin giving electrical and mechanical specifications of its full line of certified silicon rectifiers and stacks has been published by the Semiconductor Div. of Syntron Co., Homer City, Pa. Bulletin No. 300, illustrated in color, also includes a list of more than 350 JEDEC types of silicon rectifiers produced by Syntron.

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Diamond Setting Powders

A new 8½ by 11 in. two-color engineering data sheet (No. 58) describing diamond setting powders is now available from Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The new literature discusses the three grades of "compression molding" powder available and outlines their respective recommended applications. Also covered in the data sheet are such subjects as sintering temperature, Rockwell hardnesses, ductility and storage recommendations.

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Storage Vessels

Storage of liquefied petroleum gases at extremely low temperatures is the subject of a new 16-page brochure. "Cryogenic Storage Vessels." (G-50) published by Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago, Ill.

The brochure describes design of double-wall storage vessels, insulation systems, materials of construction and accessories. Illustrations include drawings and photographs of several CB&I-built cryogenic storage vessels.

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Aluminum and Magnesium Alloys

The American Society for Testing Materials has published a paperback volume on "Elevated Temperature Properties of Aluminum and Magnesium Alloys-STP-291". This publication summarizes elevated temperature, tensile and creep rupture properties of current commercially established aluminum and magnesium alloys which would normally be used at elevated temperatures.

The material included in this compilation constitutes elevated temperature data of the type used in determining allowable stresses for the Unfired Pressure Vessel Code of the ASME Boiler Code Committee. Also, every effort was made to cover those alloys used in the aircraft industry for elevated temperature applications. Both wrought and cast alloys are covered in various forms such as rolled, forged or extended rod, plate, sheet, castings, both sand and permanent mold; some data are given for alclad aluminum alloys.

The book is arranged for easy reference. A complete table of contents along with a comprehensive introduction help guide the reader to the presentation of the data. Title sheets for each alloy give the alloy designation, chemical composition, and the pertinent specifications under which various forms of the material are supplied. The Data Sheets for each alloy give a description of the material and the strength values for the mechanical properties. On the graphs, a consistent set of code symbols has been used, where practical, to distinguish types of products, test temperatures and other variables. This publication is sponsored by the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals.

Copies of this book may be obtained from the American Society of Testing Materials, 1916 Race St., Philadelphia 3, Pa., at $7.00 each.

Nondestructive Testing

A book by Warren J. McGonnagle, associate physicist, Argonne National Lab., is published by McGraw-Hill Book Co., 327 W. 41 St., New York 36, N. Y.

The physical principles, techniques, advantages and limitations of the various methods of nondestructive testing are covered comprehensively in this newly-published volume. Based upon applied physics, the treatment in the book stresses nondestructive testing as a science. It outlines the what, why, how, when and where of this rapidly-developing technology. This type of testing, the author points out, is concerned not only with the detection and location of flaws in material, but that its methods and techniques measure physical properties or nonuniformities in the physical properties of specific materials.

Among the major testing procedures treated in detail are visual testing, pressure and leak testing, liquid penetrant inspection, thermal methods, X-ray and gamma radiography, ultrasonics, dynamic testing, magnetic and electric techniques and eddy current methods.

Nondestructive test work in the field of atomic energy is emphasized. Other topics included are a complete chapter on thickness measurements, and a section devoted to such specialized techniques as spot tests, sulfur printing, spectrochemical analysis, spark testing, activation analysis, residual stress and many others.

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Industrial Innovations Save Navy Time, Money

A microswitch circuit checker, designed to simulate all possible single-circuit combinations for microswitches and plugs, and a gage to control "undercut" in welding are among 55 devices and techniques devised by Navy Bureau of Ships employees for saving time and money in machine shop and other industrial operations. These labor-saving recommendations are described in an illustrated report now available to industry through the Office of Technical Services, Business and Defense Services Administration, U. S. Department of Commerce, Washington, D. C.

X-rays for Analytical Problems

A new 4-page folder titled "Gulf's New 100 kv X-ray Spectrograph," giving details on new X-ray analytical methods for use on lubricating oils, crudes, distillates, residuals, additives and cracking catalysts, is available from Philips Electronic Instruments, 750 S. Fulton Ave., Mount Vernon, N. Y.

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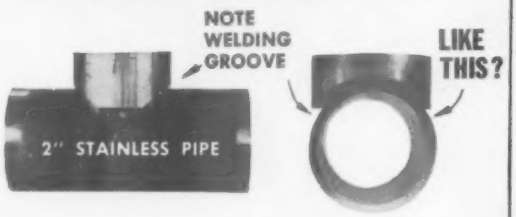

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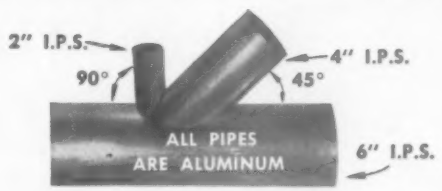

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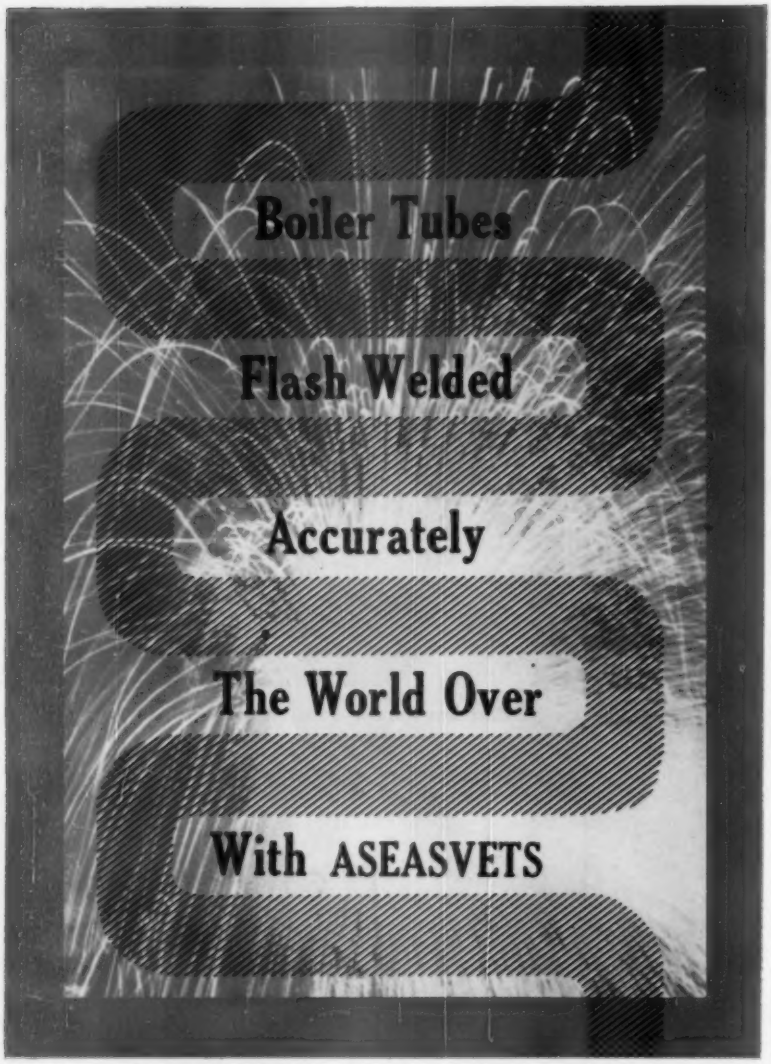

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Metals Engineering Quarterly

Engineering papers from national regional Metal Congresses now have a means of timely publication in the new *Metals Engineering Quarterly*, published by the American Society for Metals, Novelty, Ohio.

Some technical papers in the first issue, released in February include: "High-Temperature Properties of René 41 and Astroloy," "Properties of Gray and Ductile Irons" and "Fracture Toughness of Steel for Pressure Vessels."

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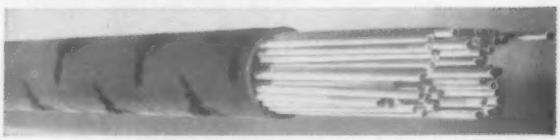
3 METHODS OF PRODUCTION BRAZING ...Which is best for you?

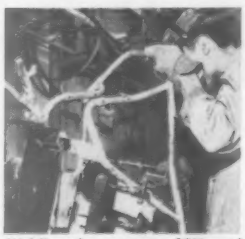
FLUX COATED ROD



A new brazing concept—engineered flux-coated bronze—thick and thin extruded coatings to fit maintenance or production needs.

Work goes fast and even with ALL-STATE's extra thin coated bronze type alloys. Flux is extruded evenly, at thickness of only .0065, to assure excellent control and easy clean-up. Narrow beads are obtained with consistent proportion of flux to rod. Coated rods are highly efficient, require minimum amounts of rod and flux.

BARE ROD AND FLUX



Welding time was cut 25% and clean-up time 75% by using All-State nickel-silver and separate flux when brazing 1" mild steel tubing in power saw frame production.

For the occasional job or where brazing operations change from time to time, ALL-STATE suggests that bare bronze with #41 or #1 flux is the most flexible method, providing maximum control of capillary flow. Recommended for deep joints.

Nickel-silver rod with #11 flux is a versatile combination for joining dissimilar metals. TS up to 80,000 psi.

The bare rod and flux method permits use of special fluxes for unusual applications.

AUTOMATIC FLUXING SYSTEM

World's largest industrial stapling machine manufacturer found solution to assembly problem with high-strength All-State #11 nickel silver and automatic Jet Flux production brazing systems.

The fastest method of surface brazing, and the most economical for production work, is automatic fluxing, available for bronze, copper and steel brazing alloys. ALL-STATE's system permits finger-tip control of liquid flux, is easy to use, requires minimum cleanup.

JET FLUX dispenser, approved by Factory Mutual, is simple to fill, operate, clean, and re-fill. Can be used to feed liquid flux in exact amounts through oxy-gas or air-gas systems. Save on fuel cost by using Liquid Jet Flux with oxy-propane or natural gas stepped up to 8 lb. pressure. Send for free information on how to adapt torch for these lower costing fuels.

ALL-STATE has quality rods and fluxes for all brazing methods. Send for folder on JET FLUX. Also free 56-page Instruction Manual and Catalog.

Distributors everywhere

All-State

ALL-STATE WELDING ALLOYS CO., INC.
White Plains, N.Y. Dial 914 WH 8-4646
QUALITY WITH SERVICE

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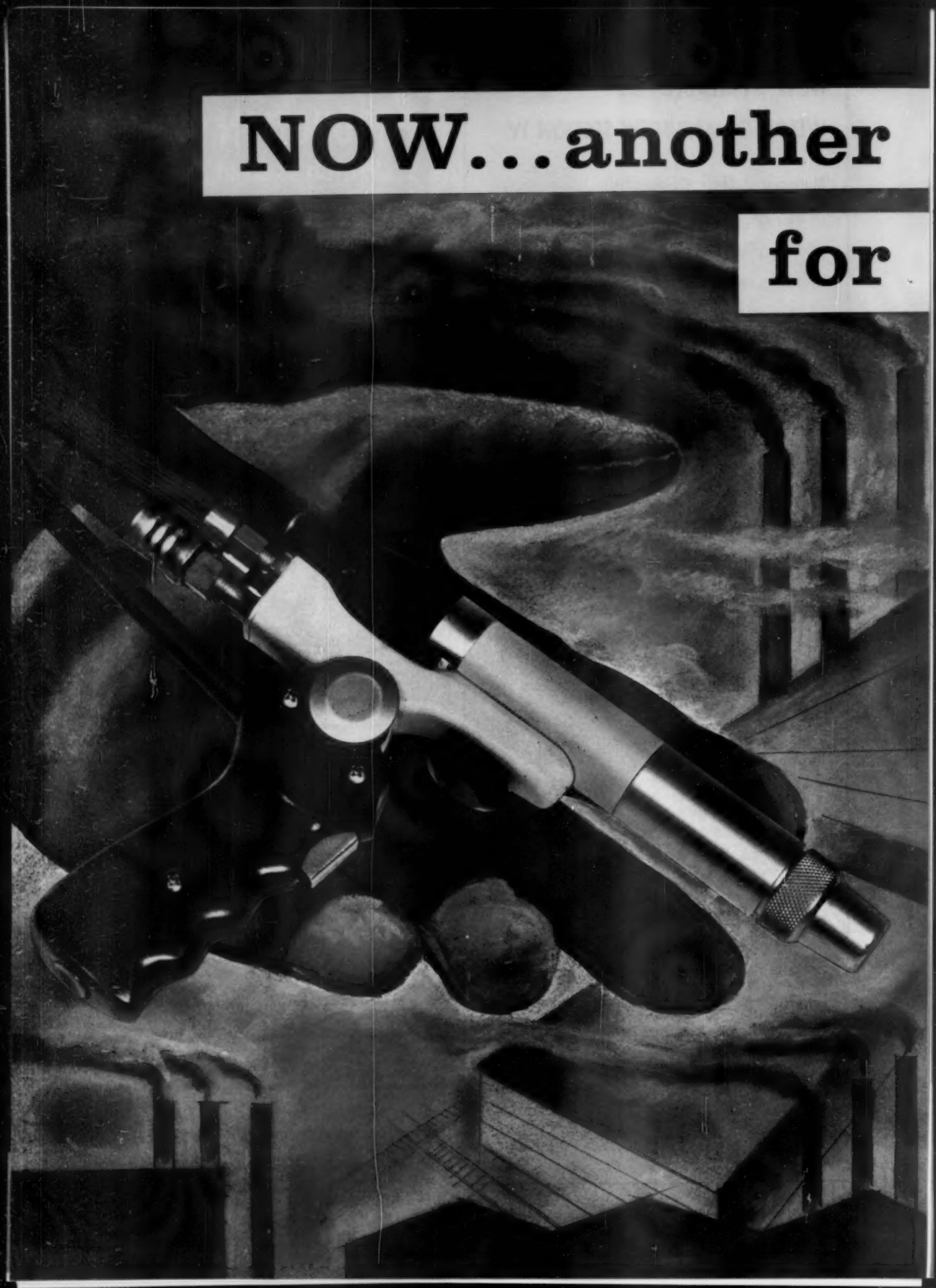


step forward

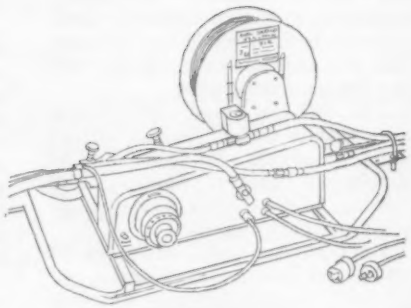
production welding

Progress means greater profits for you. The NCG AM-7 Gun for Automanual* welding is the newest, most improved consumable welding gun on the market. Its outstanding versatility, its low maintenance, its adjustable handle for welding ease and accessibility all mean increased production. And, it provides complete gas shielding using 25% less gas.

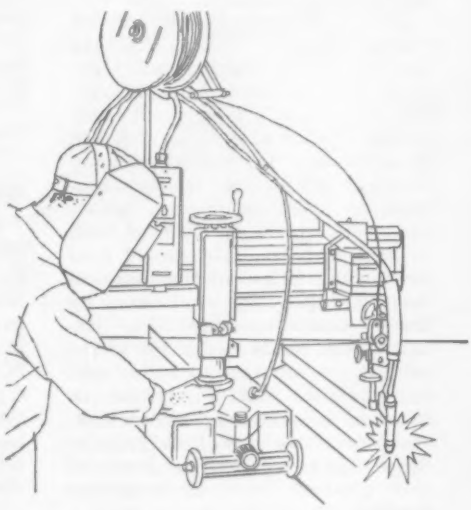
The multi-use barrel of the AM-7 Gun, designed for all MIG and carbon dioxide shielded welding processes, is interchangeable with the NCG A-10 Automatic Torch and may be used for all MIG, carbon dioxide shielded and TIG welding processes. And, for even greater versatility, a simple change of the guide tube accommodates ferrous or non-ferrous metals.

Send for complete information today. Ask for the new NCG Bulletin NH-142-E-IE. NATIONAL CYLINDER GAS DIVISION OF CHEMETRON CORPORATION, 840 North Michigan Ave., Chicago 11, Illinois.

NCG sales offices, distributors and dealers in all principal cities.



The new WC series welding control units have features that were developed to meet field requirements. Designed for consumable electrode welding processes using argon, helium or carbon dioxide shielding gases, they provide maximum versatility and economy.



Multi-purpose barrel is interchangeable with the NCG A-10 Automatic Torch for MIG and TIG welding.

NCG®

NATIONAL CYLINDER GAS

Division of CHEMETRON *Corporation*

*NCG trademark for semi-automatic welding process and equipment

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For details, circle No. 30 on Reader Information Card

CO_2 Fire Equipment for Metalworking Industry

Fast-acting and economical fire extinguishment for the metalworking industry, provided by Cardox low-pressure carbon dioxide systems, is described and illustrated in a new booklet (Form 163) available from Cardox Div. of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

Three operation-tested methods of application—direct, total flooding, and hose reels—are shown in operation and discussed. Typical metalworking "hot spots" are listed, and carbon dioxide fire-fighting installations in a number of plant areas such as pump rooms, quench and dip tanks, storage areas, and test areas are illustrated.

The booklet describes Cardox low-pressure carbon dioxide storage units, facilities for service and supply of carbon dioxide, and Cardox high-pressure systems for smaller capacity needs.

For your free copy, circle No. 69 on Reader Information Card.

Safety Guide Series

Maintaining a high standard of housekeeping cannot be over-emphasized in the handling and storage of sensitive materials, the Manufacturing Chemists' Assn., Inc., states in the latest in a series of safety guide pamphlets.

The pamphlet, SG-7, entitled "Recommended Safe Practices and Procedures—Storage and Handling of Shock and Impact-Sensitive Materials," covers all such materials other than those classified as explosives. It stresses that many chemical substances, when stimulated by shock or impact, release sudden energy in the form of heat, or heat and gas. Release of heat results in the loss of the chemical itself and possibly in damage by fire to nearby combustibles. Explosion can result in damage to the process or storage structure and any premises within range of the blast or missiles. In either case, the Association says, toxic gases or flammable vapors may be produced thus creating extremely hazardous conditions.

"Some of the 'sensitive chemicals' are used regularly in normal commercial channels and are widely known; others are less common and their use may be confined to experimental work," the pamphlet states.

The Association urges that definite areas of responsibility should be spelled out and posted in order that only those authorized and educated in safe handling procedures have access to the sensitive materials.

Copies of this pamphlet are available for $.20 from the Manufacturing Chemists Assn., 1825 Connecticut Ave., N. W. Washington 9, D. C.

X-ray for Nuclear Applications

A new 4-page folder, titled "Nuclear Problems Handled with X-rays," is available from Philips Electronic Insturments, Div. of Philips Electronics & Pharmaceutical Industries, Corp., 750 S. Fulton Ave., Mount Vernon, N. Y.

The folder is a reprint from a national engineering magazine and is illustrated with photographs and a calibration curve. The text discusses analytical procedure for uranium fuel alloy ingots; stainless steels, including 18-8 and columbium-stabilized types; silver-gold previous alloys; uranium dioxide stainless steel powder blend; and hafnium reactor control rods.

The folder describes how synthetic solution standards are prepared and used in daily operating routines. Isotopic corrections are explained together with method of applying correction factors. Techniques and equipment functions are covered. Actual test examples are cited and X-ray accuracies are given for different sample materials. Applications of the analysis method to various fuel element alloys are discussed in considerable detail.

For your free copy, circle No. 70 on Reader Information Card.

Welding HY-80 Steel

Reprints of an article by C. R. Sibley entitled "All Position Welding of HY-80 Steel with the Gas-Shielded Process" have been made available by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. The article was presented as a paper at the AMERICAN WELDING SOCIETY convention in Los Angeles last year and appeared in the October 1960 issue of the WELDING JOURNAL.

Liberally illustrated with charts and photographs, the article discusses all position welding of HY-80 steel on naval vessels, such as the atomic submarine, with the dip-transfer gas-shielded process. The modifications of the process discussed in the article point out how this welding method can be applied to HY-80 steel fabrication.

Following a short introduction and historical summary of the subject, the author discusses in detail the tests made in applying techniques to HY-80 steel and their results.

For your free copy, circle No. 71 on Reader Information Card.

(Book reviews obtained from foreign periodicals by Gerard E. Claussen, contributor of "World-Wide Welding News.")

Plastic Welding Conference (Schweissen von Kunstoffen). Vol. 18 in the series of welding books published by the West German Welding Society, 40 pp. Düsseldorf. 1960.

This book consists of four papers presented at a conference on the welding of plastics held in Cologne in 1959. The papers review the manual and automatic methods for welding pipe and foil.

—·—

Aluminum Tank Repair. Hard Cover, 6 x 8¾ in., 90 pp. Reynolds Metals Co., Richmond, Va.

The book presents detailed information on the repair of aluminum tanks. It is designed for the shop that does not know too much about aluminum.

The book gives detailed sequences of repair operations commencing with the arrival of the damaged tank at the repair shop. These include: tank cleaning, removal of damaged sections, mechanically forming repair sections and welding.

Welding procedures are covered at great length. Also included are qualification tests for the welder in order to aid training of personnel for this type of welding. Many tables are included giving typical welding conditions containing data on various welding parameters such as joint design, position of welding, filler metal, gas flow, current, etc.

The last portion of the book has a good pictorial presentation (together with explanatory text) of the actual steps in repairing various types of tank damage.

The book is available free of charge to persons making requests on company letterhead. Write to Reynolds Metals Co., Richmond 18, Va.

New Products

Torch Pilot Flame

Redesigned Asco Torches, made by Acetylene Supply Co., Woodbridge, N. J., are now available with built-in pilot flame. Where work is intermittent, this new feature makes it unnecessary to turn down the working flame, or to shut off the

torch when laying it aside temporarily. In addition, it does away with having to relight the torch after each interruption.

Two simple controls are the only moving parts. One is the main on-off knob, which also regulates the pilot flame. The other is a thumb button for controlling the size and intensity of the working flame.

For details, circle No. 101 on Reader Information Card.

Flash Welder

Designed for joining mitered corners of extruded aluminum members, a model F-3 flash-welding machine made by Thompson Electric Welder Co., 161 Pleasant St., Lynn, Mass., features a high capacity bidirectional clamping system, welding dies that nest in the extrusion, and adjustable components that allow up to one degree of angular variation to compensate for parts shrinkage.

The clamping system comprises two compound press clamps with their respective air actuating cylinders mounted on the back of the 150 kva unit. Each set of two clamps holds the work in both a horizontal and vertical plane during the weld cycle. Horizontal force is 7000 lb, transmitted to each workpiece through mechanical leverage from an 8 in. diam cylinder operating on 80 psi air pressure. A steel shaft connects the cylinder to a horizontal, mitred bronze die that moves in to clamp the work against a rear mounted stop.

For details, circle No. 102 on Reader Information Card.

Automatic Tube Mill Strip Welding Machine

A high-speed, high-strength joint that can be left in the work is claimed for a new automatic tube mill strip welder that shears, welds and planishes on a work cycle of less than 25 sec.

Mash seam welding is used on the special welder to achieve three major tube mill objectives: high-speed joining for continuous process operation; high-quality, virtually invisible weld; and high-reliability performance over other commonly used strip joining methods, according to the machine builder, National Electric Welding Machines Co., 1846 Trumbull St., Bay City, Mich.

Weld quality approximates parent metal strength, company engineers report, permitting the seam to remain in the work in most applications.

For details, circle No. 103 on Reader Information Card.

Midget Soldering Iron

Midget soldering irons with improved performance, a new handle design and redesigned tip and heater assembly will soon be available from General Electric's Industrial Heating Department, Shelbyville, Ind.

Company engineers reported that the performance level of the irons has been raised by moving the heating element in the tip even closer to the soldering surfaces.

With a new clip arrangement, the tip and heater assemblies can be changed faster and easier than with previous models, the engineers said. The entire assembly can now be pulled out of the handle, the tip and heater assembly slipped out, a new one put in and the assembly pushed back into the handle.

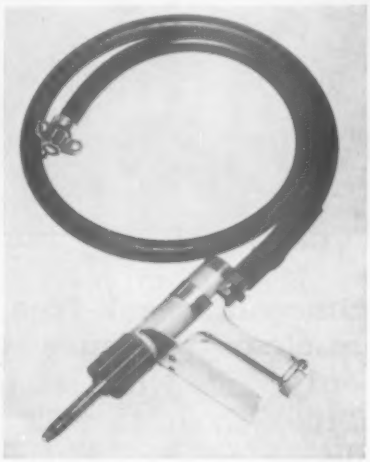
Designed for increased operator comfort, the redesigned handle will not heat up, the engineers added. The tip and heater assembly is held firmly in place. Extensive testing has shown that the tip and heater assembly will not "loosen up."

General Electric's newly designed midget soldering irons are available in $^1/_8$- to $^1/_4$-in. tip sizes with 6-v, 18- to 35-w ratings.

For details, circle No. 104 on Reader Information Card.

Heavy-Duty Torch

The model R heavy duty torch is designed for high production metal removal by Arcair Co., Lancaster, Ohio. Although this new torch can be used on any production application requiring high currents for maximum speed in metal removal,



its primary purpose is pad washing in foundry cleaning rooms.

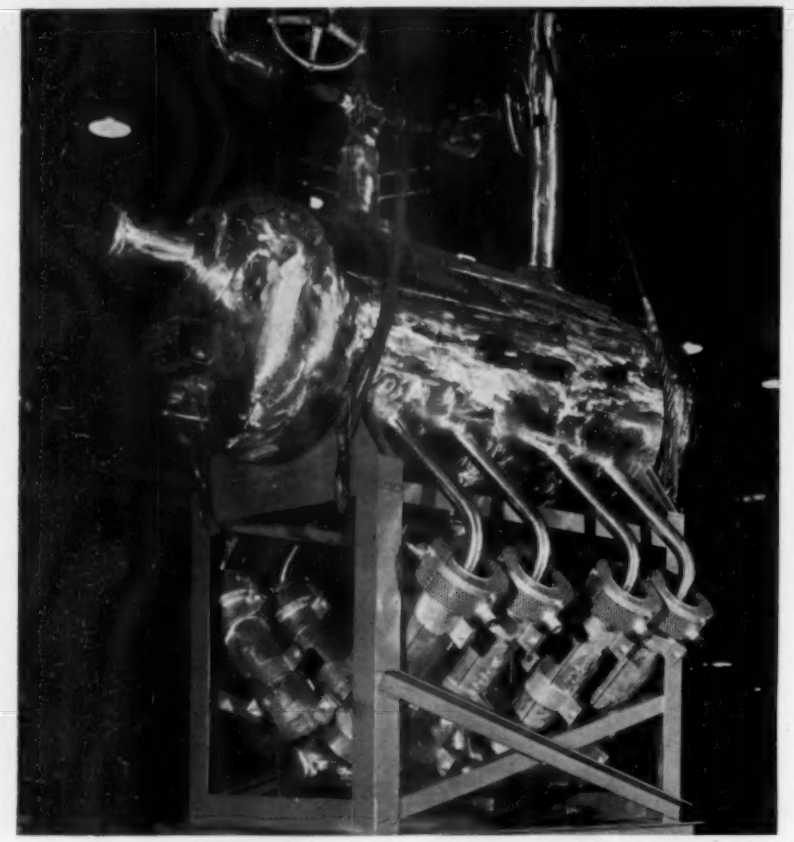
The R model torch may be used with either standard or jointed electrodes with a minimum of electrode changing time. It is available in three sizes: Model R-6 for $^3/_4$-in. electrodes; Model R-5 for $^5/_8$-in.. electrodes; Model R-4 for $^1/_2$-in. electrodes.

For details, circle No. 105 on Reader Information Card.

Hard Surfacing Electrodes

Metal surfaces subjected to a high stress gouging type of wear are getting new life thanks to The McKay Co., 1005 Liberty Ave., Pittsburgh 22, Pa., producers of new Hardalloy 55 hard-surfacing electrodes.

ARCOS EB INSERT FOR ROOT PASS WELDING



Job report courtesy of Dominion Bridge Co., Ltd., Montreal, Quebec

Smooth, crack-free root welds made in nuclear pressure vessel from one side only. This NRU reactor surge tank is made of Type 347 stainless, 3" thick with 26" I.D. It is designed for operation up to 630°F. at 2400 psi. Because welding could be done from the outside only, Arcos EB Consumable Weld Inserts were used for the root passes. Result: complete fusion, crack-free, with smooth inner surface. Write today for complete data on EB Weld Inserts.

ARCOS

Arcos Corporation • 1500 S. 50th St. • Philadelphia 43, Pa.

For details, circle No. 31 on Reader Information Card

McKay Hardalloy 55 is a high alloy, low hydrogen hard-surfacing electrode designed to resist severe wear under high stress conditions. It reportedly has good out-of-position characteristics and operates either a-c or d-c reverse polarity. Deposits retain hardness at relatively high temperatures. They cannot be forged at any temperature and will not respond to heat treatment.

Hardalloy 55 operates well out of position and with a minimum amount of splatter. Weld deposits are covered with an easily removed slag which does not pop off when used on austenitic manganese base metal.

Relief checks will occur but they are not detrimental to wear properties of the alloy. Severe abrasion resistance under high stress wear conditions coupled with moderate corrosion resistance and hot hardness up to 900° F make Hardalloy 55 suitable for many wear applications.

Sizes available are: $^1/_8$, $^5/_{32}$, $^3/_{16}$ and $^1/_4$ in. in standard 14 in. lengths. Each pound of electrode covers from 21 to 24 sq in., $^1/_8$ in. thick.

For details, circle No. 106 on Reader Information Card.

Processes Combined

Clam shell forming and CO-2 arc welding have been combined in a continuous automatic process developed by National Electric Welding Machines, Bay City, Mich., making possible for the first time fabrication of cylinders from steel plate by this method.

Metalworking engineers have generally considered arc welding and forming of steel plate incompatible in automatic sequence because of such factors as joint fit-up, metal elasticity and weld quality. This is especially true where the cylinder is to be expanded, which places forming and welding techniques to a severe test. As, for example, with heavy-duty motor frame shells where wall thickness may run as high as $^1/_4$-in., and the metal may be expanded by more than $1^1/_2$ in. to an exact inside diameter.

But by taking advantage of the expansion step, engineers at National Electric have developed a dual process machine that achieves production rates unheard of in this field.

Other arc welding methods than CO-2, such as argon and submerged arc, can be used with the process in a wide range of applications where cylinders are formed of steel plate.

Production rates up to 125 units an hr are claimed on 6-in. high cylinders of $^3/_{16}$-in. stock.

For details, circle No. 107 on Reader Information Card.

High Stability Current Regulated Power Supplies

High stability current regulated power supplies eliminating the need for using motor generator systems to maintain precise current control have been developed by Automation Industries, Inc., 3613 Aviation Blvd. Manhattan Beach, Calif., for marketing by the company's Magnetics Division. The power supplies utilize two separate control circuits which function independently, although both are completely contained in the power supply package. The control circuits are self-adjusting and compensate for both slow and fast variations resulting from dynamic input or output changes. The desired current output is obtained by simple adjustment of a single high precision potentiometer control. The current output thus selected will maintain regulation of better than 0.02% (2 parts in 10^4).

The controller circuits componentry is effectively the same for all power supplies up to 30 amp output. High stability current regulated power supplies with current output greater than 30 amp are customed engineered to suit specific applications.

For details, circle No. 108 on Reader Information Card.

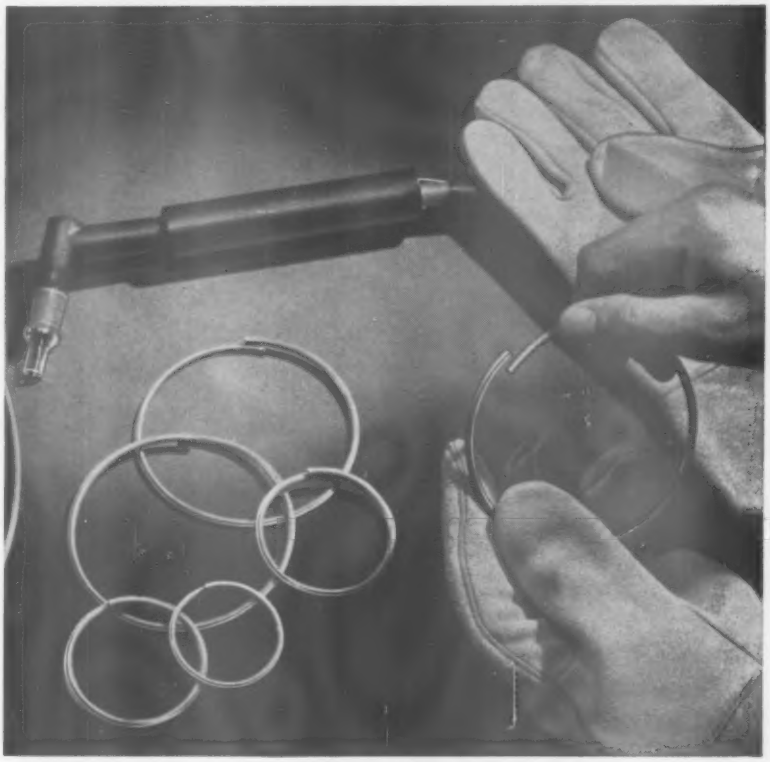
Balanced-Wave Power Supply For Tungsten-Arc Welding

Designed specifically for high-performance inert-gas welding with nonconsummable electrode, a new type of "balanced wave" power supply is now available from the Glenn Pacific Corp., 703-37th Ave., Oakland, Calif., after more than a year of on-the-job field testing.

The circuit design provides a capacitor bank in the secondary circuit and employs nonsaturable reactor and transformer design to assure balanced electron flow between electrode and workpiece. Full electron flow in both directions greatly improves the removal of surface oxides on aluminum welding, and reduces arc fluctuation and sputter to provide dense, clean welds of excellent appearance.

Built-in high frequency generator provides arc ignition without contact between electrode and workpiece, eliminating contamination.

ARCOS EB* INSERT FOR ROOT PASS WELDING



When pipe joints must be completely dependable. The Arcos EB Weld Insert produces smooth, uniform, crevice-free root pass welds that do not cause turbulence or impede liquid flow. It is used for making root passes where accessibility is limited to one side and where highest quality in the root pass is essential to the integrity of the completed weld. A new booklet describing the Arcos EB Weld Insert is yours for the asking. Write for your copy today.

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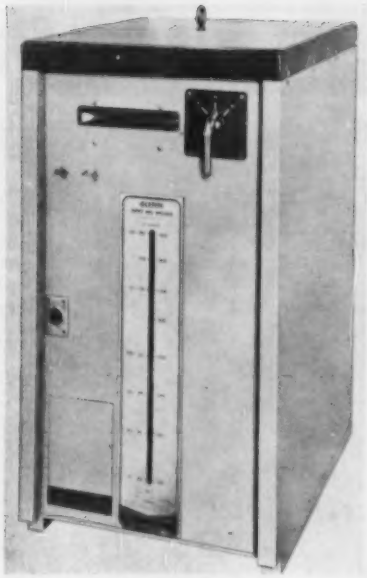


Automatic safety controls cut off high frequency except when starting. Infinitely-variable motorized current control is provided throughout three overlapping switch ranges: low, 28 to 58 amp; medium, 53 to 175; high, 165 to 400 on 150-v scale. Other voltages have slightly lower current values.

Two models are available. Model BW400-AC delivers ac only, with selectable open circuit voltages of 100 and 150. Model BW400-AC-DC includes a heavy-duty rectifier bank and delivers either a-c or dc, with 150 v open circuit on a-c and 80 v on d-c. This makes it a truly universal power supply for the gas-shielded-arc processes as well as stick-electrode manual welding.

Optional equipment for both models includes built-in gas and water controls and a remote-control foot switch for "on-off" and current control.

For details, circle No. 109 on Reader Information Card.

Rebuilding Tractor Grouser Shoes

The Victor grouser shoe/sprocket reconditioner, a new machine for rebuilding tractor grouser shoes and drive sprockets to factory specifications, now is being marketed by Victor Equipment Co., 844 Folsom St., San Francisco 7, Calif., manufacturer of welding apparatus, gas regulators and hard-facing rod.

This rebuilder combines automatic flame cutting with submerged-arc automatic welding to give the operator a completely automatic method of trimming tractor pads and rewelding new grouser bars onto them. In addition, the machine automatically trims worn tractor sprockets and welds new sprocket rings onto the hub. Its cutting torches and semiautomatic welder can also be used on other jobs.

Time required to setup, trim, weld and unload a D8 grouser shoe on this machine is only 11 min; a D8 sprocket rim can be rebuilt on it in less than 2 hr.

The machine uses 500 amp a-c power. Space required by grouser fixture is $8^1/_2$ x $12^1/_6$ ft; by sprocket fixture, 4 x 4 ft.

For details, circle No. 110 on Reader Information Card.

Precision Welding Power Supply

Model 1046 MA Capacitor-Discharge Power Supply manufactured by Weldmatic Div./Unitek, 950 Royal Oaks Dr., Monrovia, Calif., is designed to provide the accuracy required in welding extremely fine wires, such as: strain gage assembly

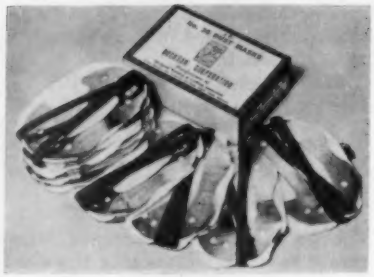
and attachment; deposited metal bonding; electronic circuitry junctions; ribbons and foils; and wherever microminiature joints of parent metal strength are required. The increased sensitivity of this model reportedly provides a higher degree of control in the manufacturing process. Dual-range feature permits operation in a low range of 0.004 to 1.3 w-sec or a high range of 0.04 to 13 w-sec.

For details, circle No. 111 on Reader Information Card.

Low Cost Dust Masks

Low cost, lightweight No. 36 dust masks, packaged in a compact, 10-unit, color-coded carton for easy stacking and cleaner handling, are now available from Dockson Corp., 3839 Wabash Ave., Detroit 8, Mich., manufacturers and distributors of a complete line of modern welding and safety equipment.

Made of pliable aluminum which permits close fitting around mouth and nose contours, these feather-



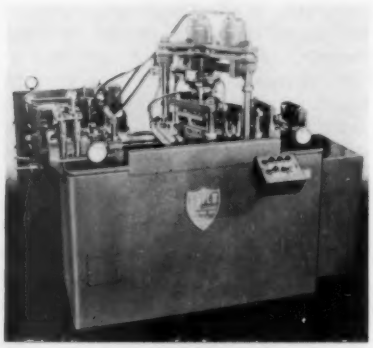
weight dust masks offer maximum comfort and protection against hundreds of different dusts.

Inexpensive, throw-away, sterilized cotton gauze filters are held snugly against the face, filtering dirt particles from the air while allowing exceptionally free breathing and clear speech.

For details, circle No. 112 on Reader Information Card.

Shear–End Welding Machine

An automatic combination shear and end welder designed to provide continuous strip for roll forming, tube manufacturing, punch press operation and coil-strip processing lines is now being produced by Guild Metal Joining Equipment Co.,



7280 Wright Ave., Bedford, Ohio. The new rocker-die combination unit utilizes the mesh seam process to join coil strip ends for continuous processing lines, and has fast-cycle capacity.

Complete operation time for clamping, shearing and welding will range from 15 to 25 sec, depending upon material thickness and width, increasing production as much as 30%.

For details, circle No. 113 on Reader Information Card.

Plasma Jet Cuts Under Water

Recent investigation by Plasmadyne Corp., 3839 S. Main St., Anaheim, Calif., manufacturers of Plasmatron plasma-jet spray-coating equipment has shown that the

SCIAKY ELECTRON BEAM WELDING

Here's how you can combine precision research and practical production electron beam welding in one equipment installation

Whether your interest in electron beam welding processes is for highly precise research or practical production work—or both—your data should be complete with details on Sciaky machines. They are most simple and practical in concept and operation.

GUN DESIGN GIVES EXCEPTIONAL ELECTRON OPTICS

The Sciaky Electron Gun produces specific beam density previously possible only with accelerating potential higher than 100,000 volts. The Sciaky gun, entirely contained within the atmosphere of the welding chamber, will operate in any angular position. *Both* gun and fixture can be moved to any position within the chamber while welding.

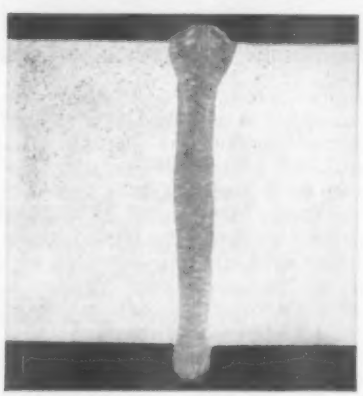


Figure 1

Advanced focusing design results in electron beam welds of 12 to 1 depth to width characteristics. Figure 1 shows a deep penetrating butt weld in type 304 stainless steel. Plate thickness is .5". Note lack of heat-affected zone.

GUN AN INDUSTRIAL TOOL

The gun construction is simple and rugged. Precise alignment is inherent in design, and is not dependent upon assembly adjustments. If necessary, filaments can be easily and quickly replaced in less than five minutes. As shown in Figure 2, the Sciaky Electron Beam Gun is small and

Figure 2

compact. A simple spacer arrangement optimizes gun optical system throughout a wide range of output power without compromise of specific beam energy. As a result, the

Figure 3

Sciaky gun is optimized at current ranges of 250, 150, 100 and 50 MA. at 30,000 volts. Output power is continuously adjustable within each range.

EFFICIENT PUMPING SYSTEM

Evacuation of chamber to welding pressure is obtained within 3 to 10 minutes, depending on chamber size. Pumping sequence is fully automatic, and without any manual adjustment. Automatic safety devices insure trouble-free operation and full protection of system.

RADIOLOGICAL HAZARDS ELIMINATED

Low voltage (30,000 v. maximum) and highly refined chamber design eliminate x-ray hazards to operator, which are a severe problem with higher voltage equipment. As a result, the Sciaky low voltage system needs no costly shielding, even when welding at highest output.

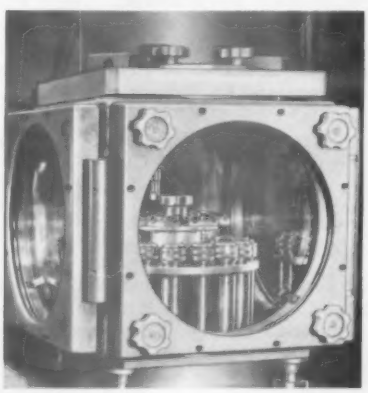


Figure 4

As shown in Figures 3 and 4, complete accessibility and visibility are provided by this latest Sciaky design. All sequence controls of the dial feed unit (Figure 4) are fully automatic. This production unit is being used to weld end-caps to tubes.

Regardless of your specific area of interest, you'll find the Sciaky combination of welding experience and electron beam technology is well advanced. Sciaky is Exclusive Licensee under Stohr, U.S. Patent 2,932,720.

81C8102

Please write for information — without obligation, of course!

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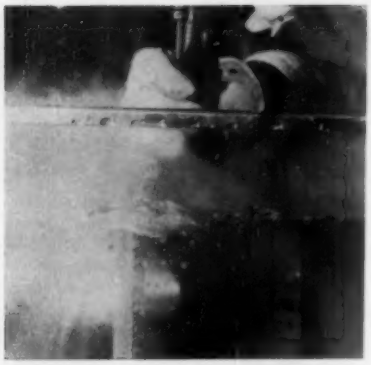


gun will successfully cut through a series of metal plates submerged in water within a matter of seconds.

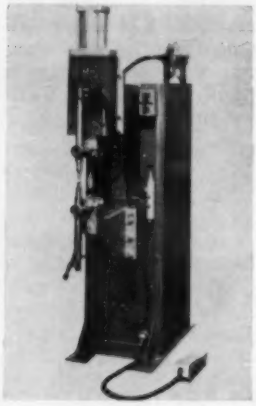
According to Plasmadyne engineers the use of inert gases as the plasma medium allows the successful cutting of any metals under water without the danger of contamination of either the water or the metallic surface. They also noted that arc temperatures from 3 to 5 times that of an oxy-acetylene torch may be achieved. As a result, the new technique is applicable for use in areas where rapid cutting is a requirement or in applications concerning the cutting of toxic materials.

For details, circle No. 114 on Reader Information Card.

Medium Duty Spot-Welding Machine

Electro Machan-Heat Ltd., Lower Teddington Rd., Kingston-upon-Thames, Surrey, England, have recently introduced the Type M.50 Mk.III medium-duty spot welder, which has a nominal rating of 50 kva at 50% duty cycle and has been designed primarily for use with 18–22 gage bright mild steel sheet.

The machine, producing up to 300 spot welds per minute, is suitable for stitch-welding and reportedly will be of particular value in the motor industry or in sheet metal working shops, where high spot-welding speeds are required.



The welding head has a very low coefficient of friction, being fitted with hardened steel rollers mounted on ball bearings and machined at the periphery to a V-shaped profile. This "V" profile engages the knife edge of a hardened steel guide, so that contact is made over a very small working surface and easy movement of the ram is assured.

The machine is equipped with a standard Electro Machan-Heat stacked-core transformer. Heat regulation is obtained through an 8-position tap link panel. The equipment is normally supplied to operate on any two phases of a 400/440 v 50 cycle 3-phase supply.

For details, circle No. 115 on Reader Information Card.

Welding Helmet with Neoprene Lens Holder

An entirely new welding helmet has been announced by the Chicago Eye Shield Co., 2727 W. Roscoe St., Chicago 18, Ill. A moulded neoprene lens retainer mounts on the helmet without fasteners of any type. This, in combination with new delrin pivot assemblies and nylon chin rest bolts eliminates all electrical conductivity between the exterior and interior of the helmet. The helmet shell is fiber glass.

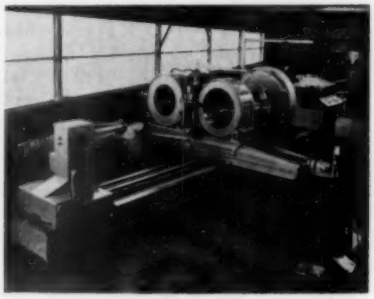
The retainer accommodates

$4\frac{1}{2}$ x $5\frac{1}{4}$-in. size lenses. Wearers of bifocal glasses are said to benefit greatly from the increased downward viewing area. In this helmet a choice of conventional glass plates or plastic filters may be used. With plastic filter, the helmet is said to be 7 oz lighter than helmets with glass lenses and metal retainers of the same size. The rubber retainer reportedly is an excellent shock absorber and prevents the breakage of lenses which might result if the helmet is dropped. The retainer also provides considerably less heat transfer from exterior of helmet than will metal retainers.

For details, circle No. 116 on Reader Information Card.

Weldlathe For Internal Girth Welding

Recently announced by Berkeley-Davis, Inc., 1021 Bahls St., Danville, Ill., this machine is designed for the internal girth welding of seams in rocket shells. It is equipped with a cross-slide and two cathead assemblies so that two different diameters of shells can be welded without changing tooling. The tooling consists of external



copper closing rings which are machined at a temperature of 600° to a ±0.005-in. tolerance, the diameter being mathematically correct for a shell which is heated to the same temperature. Backup gas is provided in the heated copper bands split into four segments with a special mechanical motion to permit a flange or lip to pass through the tooling without disassembly.

The welding equipment is carried on the end of the long boom assembly, and the gas-shielded-arc welding processes are used. The welding heads are mounted at the back of the boom, and the drive shafts extend through the boom, to the front end, where the drive rollers for the wire feed are located. The whole welding head assembly is mounted on a pivoted slide so that the unit can go through an opening of approximately 24 in., and still reach the bottom of a tank or shell 6 ft in diam.

The machine is 60 ft long, 14 ft high, 23 ft wide, and weighs 54 tons.

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Portable X-ray Unit

Versatile radiography in all power ranges under widest variety of in-plant and in-field conditions is made possible through two basic design changes in the recently introduced

Baltograph 300-kv portable X-ray unit designed and fabricated by the Balteau Electric Corp., Stamford, Conn. It is offered in two model versions. One model incorporates a 360 deg X-ray tube allowing circumferential radiography as well as single beam use. The other model has a conventional single beam operation. Both models are easily converted one to the other at any time. The Baltograph 300 has a power rating of 300-kvp–3 ma, a penetration capability up to 4 in. of steel and a total net "carrying" weight of 136 lb.

For details, circle No. 118 on Reader Information Card.

Electronic Tracer

A new economical electronic tracer for cutting work of a non-repetitive type or where a minimum investment in templates is necessary is being marketed by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y.

Designated Aircotron Model "J" Electronic Tracer, the unit uses templates prepared by conventional drafting methods, cutting costs of the templates and finished work. Customer advantages of stepless cutting speed control and tracing of 90 deg corners are provided.

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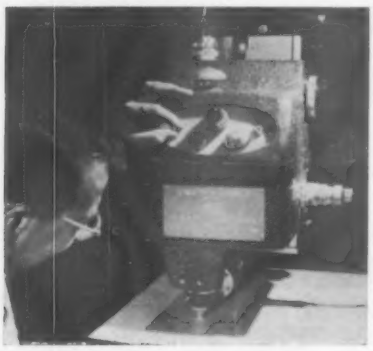

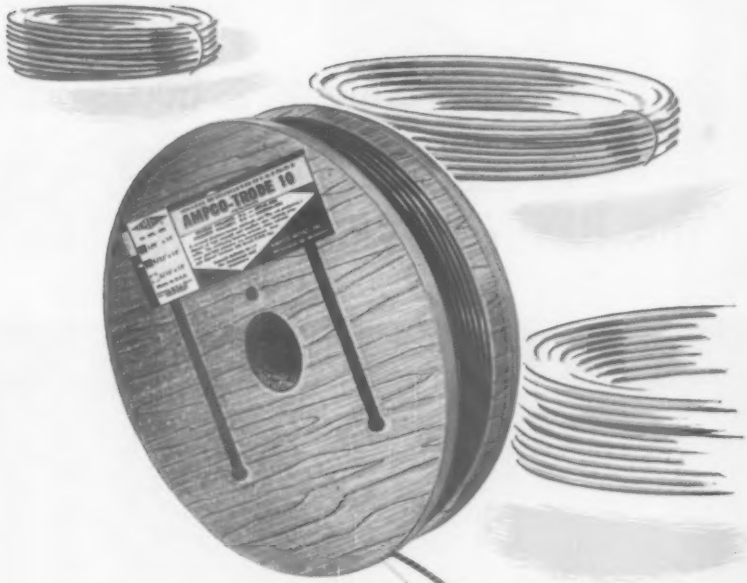

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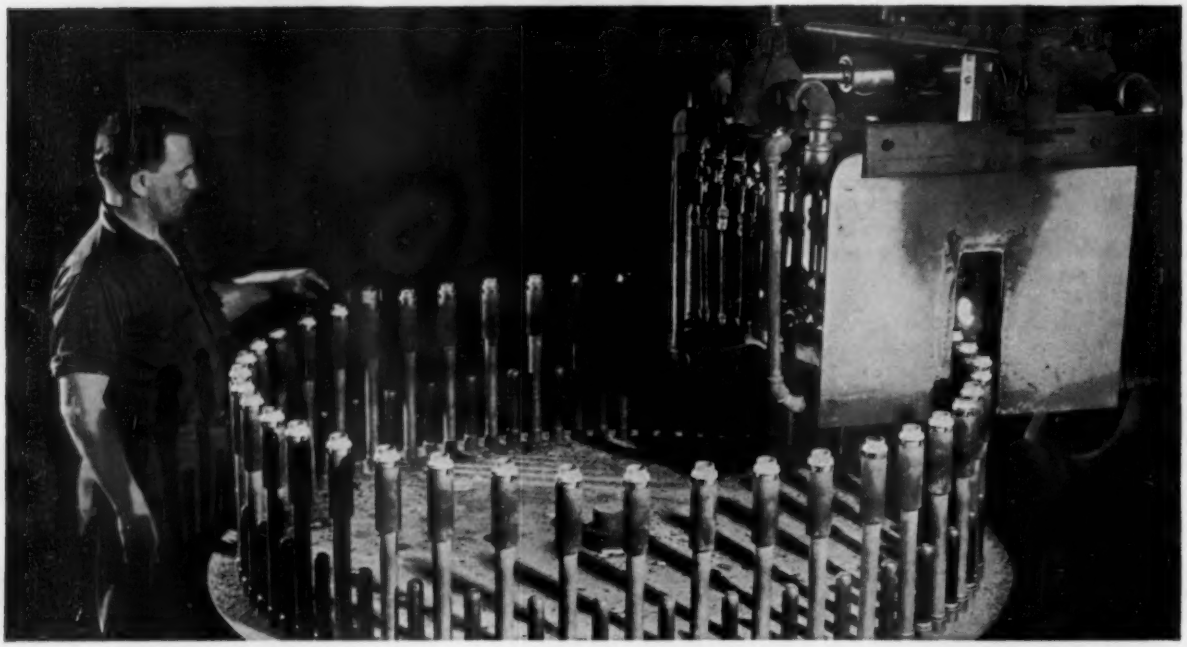

Rotating jig showing mounted assemblies entering and leaving gas-air furnace.

Left– brazed assembly. Right– components with preform ring of EASY-FLO *45.*

This Hartford, Connecticut, company makes—in volume—an assembly that goes into the overflow system of household appliances. The assembly consists of brass tubing and a machined brass casting. The two components are joined by a preplaced ring of Handy & Harman EASY-FLO 45 silver brazing alloy and HANDY FLUX. Heating is automatic gas-air; parts are placed on a rotating turntable to pass through the gas furnace. Every 60 working minutes, 650 assemblies are completed.

The advantages here are that the manufacturer can use thin-walled tubing with heavier, threaded components at no sacrifice in strength. Because of EASY-FLO's penetrating qualities, the entire shear area is fully as strong as the solid parts of the assembly, yet considerably lighter. And, casting and machining the components for this assembly have been greatly simplified.

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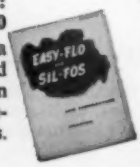

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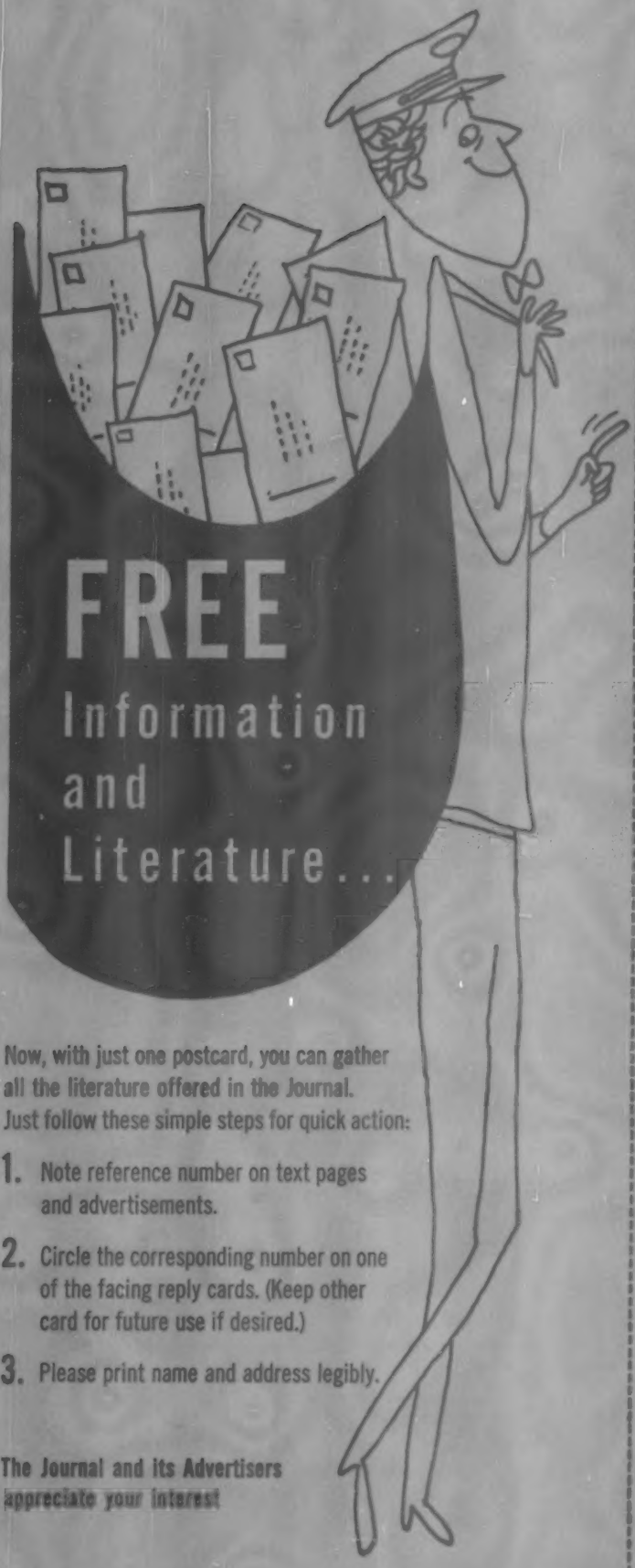

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SUPPLEMENT TO THE WELDING JOURNAL, MAY 1961

Yield Strength of E9018 Weld Metal

Welding technique can vary yield strength of E9018 weld metal by 20,000 psi

BY W. L. WILCOX AND H. C. CAMPBELL

ABSTRACT. This investigation was conducted to determine the causes of yield strength variations between user acceptance tests and the manufacturer's quality control tests of E9018 electrodes. Its results show the effect of using stringer beads as well as low preheat and interpass temperatures on increasing the strength of the weld metal in both the as-welded and stress-relieved conditions.

Introduction

Yield strength values for E9018 weld metal in the as-welded condition have differed by as much as 20,000 psi between tests made by the manufacturer in certifying each lot of electrodes and the tests run by the user in accepting the electrodes. The tests in each case were conducted in accordance with the provisions of the MIL-E-19322A(SHIPS) specification. These electrodes are currently being used in submarine construction.

It is generally recognized within the welding industry, although sometimes overlooked, that variations in welding conditions and procedures can alter the properties of the resulting weld metal—particularly low-alloy steel weld metal. This investigation was conducted in an attempt to determine, for the yield strength of E9018 weld metal, the magnitude of the effects of welding variables within the ranges currently encountered in electrode testing and subsequent fabrication.

W. L. WILCOX is Product Manager, and H. C. CAMPBELL is Director of Research, Arcos Corp., Philadelphia, Pa.

Paper presented at the AWS 42nd Annual Meeting in New York, N. Y., Apr. 17–21, 1961.

Table 1—E9018 Weld Metal Chemistry

	Lot OB11A[a]	Lot 501 HT 79L432[b]
C	0.046	0.05
Mn	0.88	0.96
Si	0.37	0.30
S	0.015	0.012
P	0.018	0.013
Cr	0.12	0.12
Ni	2.16	1.67
Mo	0.37	0.29
V	0.00	0.01

[a] Weld pad.
[b] Outside report—details unknown to the authors.

Test Procedure

Selection of Test Conditions

Eight test plates were welded with two different brands of $^5/_{32}$-in. E9018 electrodes. Procedures encountered in actual submarine hull construction were used along with those permitted for the lot inspection tests of electrodes as required by specification MIL-E-19322A(SHIPS) for quality assurance purposes.

In the present tests, all electrodes were used just as they came from their containers without rebaking. Mechanical testing of the weld metal was conducted on 0.505-in. diam tensile bars in both the as-welded and heat-treated conditions. Specimens for the "as-welded" tests were machined and tested immediately upon completion of welding, and were not given the benefit of aging. The tensile data reported were obtained in accordance with Federal Test Method Standard No. 151, July 17, 1956.

Selection of Electrodes

The particular lots of E9018 electrodes were selected on the basis of availability and the fact that considerable information about them had been obtained from previously conducted standard quality

Table 2—E9018 Weld Metal Mechanical Properties (As-welded Condition)

Test	Electrode	Condition	Yield Strength ksi	Tensile Strength ksi	Elongation in 2 in., %	Reduction of area, %
A	OB11A	MIL-E-19322A, Restrained groove	83.7	96.6	24	64
B	OB11A	MIL-E-19322A, Restrained groove	84.2	96.2	25	66
C	OB11A	Inspection plate	97.0	103.9	21	62
D	OB11A	Inspection plate	79.0	93.0	27	64
E	501, HT 79L432	Outside report[a]	91.0	100.5	23	60

[a] Specific test details unknown to the authors.

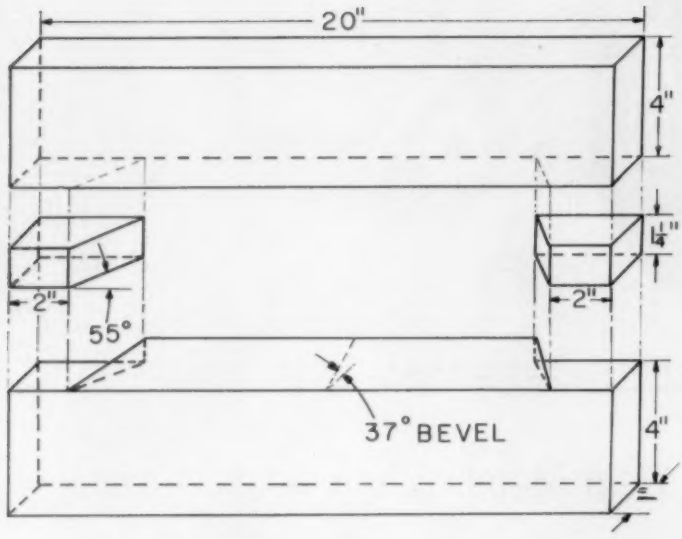

Fig. 1—Combination restrained groove inspection plate test

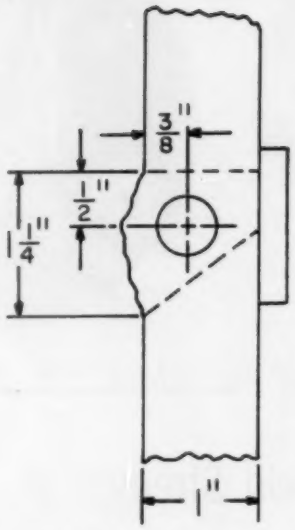

Fig. 2—Cross section of test joint and location of tensile bar

control tests. This information, shown in Tables 1 and 2, was required to establish each electrode's conformance with the specification and was further useful for correlation with the present test results. Except for nickel, the weld metal chemistry of the two brands of E9018 electrodes was strikingly similar. This, however, was not a consideration in their selection.

The weld metal chemistry for each of the lots of electrodes is shown in Table 1; the mechanical properties are in Table 2.

Selection of Base Metal and Joint Type

T-Steel was selected as the base metal because of its strength and the fact that it is, for these electrodes, permitted by the electrode specification for the inspection plate test.

The selection of the joint design and dimensions for the test model was based on the desire to provide some restraint and, with a minimum of welding, to obtain sufficient weld metal for the required tensile and Charpy specimens, plus some indication of electrode usability. Each joint was intended to provide two tensile bars and ten Charpy specimens, from which both as-welded and heat-treated mechanical properties could be determined. The test model is shown in Fig. 1. A cross section through the groove, in a test plate ready for welding, would be very much like that of the inspection plate in MIL-E-19322A(SHIPS) and would be of proper root dimension, including the backing strip, for a $^{7}/_{32}$-in. electrode. This cross section and the tensile bar location are shown in Fig. 2.

Preparation of Test Joint and Weld Specimens

Flame cutting and sawing were employed in preparing the various components of the test model. All mating flame-cut surfaces and those on which weld metal would be deposited were hand ground to remove the oxide layer prior to fitting and tacking.

Preheat was applied with an oxyacetylene flame and throughout the tests temperature-sensitive crayons were used as temperature indicators.

D-c motor generators and rectifiers with drooping characteristics were used to supply the welding current. Amperages were checked periodically with a tong meter. Near the completion of the tests, individual voltage and amperage readings were taken for each welding unit on recording Esterline-Angus meters. The selection of the actual welding currents used was based on welder preference within the requirements of the specifications. Travel speed readings were taken during the tests to form a basis on which to compute heat input.

All plates were allowed to air cool to the required interpass temperature and to room temperature on the completion of welding. Each joint was cut in half on a power saw to provide the specimens required for testing in the as-welded and heat-treated conditions. The heat treatment applied was that specified in MIL-E-19322A(SHIPS). The specimens requiring heat treatment were all treated at the same time in the same oven.

The 0.505-in. diam tensile specimens were prepared from each plate by saw cutting and machining. Yield strength determinations were made in accordance with the extension-under-load procedure of Federal Test Method Standard No. 151.

Test Results

In both the as-welded and heat-treated conditions, considerable variation was encountered in weld metal tensile properties as a result of changes in welding position, width of weave, and preheat and interpass temperature. The overall range was 17,000 psi in tensile and 21,000 psi in yield strength in the as-welded condition for the E9018 electrodes of Lot OB11A. In the heat-treated condition the ranges were about 15,000 and 14,000 psi respectively. These results are summarized in Table 3.

A comparison of the results of Tests F and G in Table 3 shows that some reduction in weld strength accompanies the use of higher preheat and interpass temperatures. The trend was first indicated in test D of Table 2. Test F was considered an example of an accepted fabrication procedure, whereas G and H in addition to Test L represent procedures permitted in welding the "Inspection plate test" in MIL-E-19322A(SHIPS) from which the weld metal Charpy test specimens are obtained.

An examination of the results of Tests F, H and J of Table 3 and C of Table 2 compared with I and K of Table 3 and A and B of Table 2 shows clearly the higher

Table 3—Welds in Combination Restrained Groove of Fig. 1

(5/32-in. E9018 electrodes. Specimens F thru K: Lot OB11A. L & M: Lot 501 HT 79L432. Base Metal: T-steel)

Specimen	Position of welding[a]	Bead type[a]	Preheat and interpass temperature, °F		Arc volts	Amperage DCRP	Forward travel speed, ipm	Heat input joules/in. ÷ 1000	Condition[b]	Yield strength, ksi	Tensile strength, ksi	Elongation in 2 in., %	Reduction area, %
F	H	S	125	150	21–22	160	6.2, 9.0	33.2, 23.0	AW	94.0	101.5	21	64
									HT	92.4	98.0	24	62
G	H	S	200	500[c]	21–22	160	9.6	21.5	AW	88.7	93.7	28	70
									HT	85.5	92.5	28	68
H	V	S	125	150	21–23	120	4.3	35.8	AW	99.7	108.5	19	56
									HT	92.9	101.5	23	64
I	V	W-4D	125	150	22–23	130	1.7	103.0	AW	86.2	101.6	24	64
									HT	88.7	98.7	26	58
J	F	S	125	150	23–25	185	8.4	31.5	AW	91.8	97.2	24	66
									HT	89.0	91.0	26	65
K	F	W-4D	200	250	22–24	175	5.1	47.2	AW	78.3	91.2	24	66
									HT	79.6	86.2	28	70
L	H	S	200	500[c]	21–22	165	7.9	27.0	AW	92.7	100.1	26	68
									HT	92.2	99.4	26	64
M	H	S	125	125	21–22	160	7.1, 6.0	29.1, 33.4	AW	106.2	113.2	20	51
									HT	100.2	109.2	24	62

[a] H—Horizontal; V—Vertical; F—flat; S—stringer beads; W-4D—weave beads, width 4 × electrode diam
[b] AW—as-welded; HT—1150° F, 2 hr., FC.
[c] No attempt was made to control maximum interpass temperature; during welding, the plate temperatures did not fall below 400° F after once achieving that temperature level.

strength of stringer beaded weld metal irrespective of the position of welding and the amperage used.

Tests L and M of Table 3 to which E9018 electrodes from lot No. 501 (a different brand from lot No. OB11A) were subjected, involved only a difference of 75° F in preheat temperature but as much as 375° F in interpass temperature. This produced strength level differences of about 13,000 psi in both tensile and yield strengths in the as-welded condition, and 8000 and 10,000 psi respectively in the heat-treated condition.

The purpose of these two tests was to provide a basis for comparison of the properties of two different brands of E9018 electrodes. A comparison of the results of Tests F and G with those of M and L respectively reflects the characteristically higher weld metal strength level produced by the stringer bead technique.

An examination of the fractured surfaces of the tensile bars indicated sound, ductile fractures for all heat treated bars. As-welded bars H, I, K, L and M contained small fish eyes.

Discussion

Width of weave and position of welding (which undoubtedly are related to the amperage that can be used) appear to be more influential than preheat and interpass temperature in their effect on the resulting weld metal strength. In all cases, regardless of the position of welding, the use of a stringer bead technique resulted in the highest strength weld metal.

The effect of heat input is more difficult to interpret, since the highest computed heat input did not result in the lowest strength levels nor, conversely, did the lowest heat input result in the highest weld metal strength. A macro- and microstructure study would be in order in that the effect of factors such as bead thickness resulting from position of welding should be considered in addition to heat input.

Heat input as an exacting means of controlling joint properties is difficult to handle, however, since a welding operator very often

Table 4—Divergent Purposes of Inspection Tests and Ultimate Use (E9018 Electrodes)

	Restrained groove inspection test[a]	Inspection plate[a] for lot acceptance	Use in fabrication[b]
Purpose	Demonstrate soundness, tensile properties	Demonstrate usability, soundness, toughness	Obtain sound, serviceable welds
Position of welding	Flat	Horizontal (7/32–5/16 in. flat)	All
Welding technique	None specified	None specified, but position dictates stringer beads up to 7/32-in. electrodes	None specified
Base metal	None specified	HT, A302 or T-1 Steel	Base metals with properties similar to those of weld: use E9018. Butt joints[c] in HY-80 and T-1 steel: use E-11018
Preheat and Interpass temperature	100° F maximum	200° F minimum with T-1 steel. 300° F minimum with HT or A302	70 and 125° F minimum, depending on plate thickness. 300° F maximum regardless of other conditions
Heat input	None specified	None specified	Maximums stated for certain plate thickness groups

[a] Specification MIL-E-19322A(SHIPS).
[b] General specifications for ships. Section S9-1.
[c] MIL-10018 is recommended in MIL-E-19322A(SHIPS) for other joints in HY-80 steel.

changes his travel speed to suit local conditions, particularly in out-of-position work. For this reason, average heat input computations for a heavy joint based on a few travel speed readings may be considerably in error.

In weave beads, the accuracy of heat input calculations based only on linear considerations may be questioned. As the width of weave increases and the forward travel speed decreases, it becomes necessary to consider the lateral dimension. Perhaps a volume or area factor should be included in such calculations.

The decrease in yield strength resulting from heat treatment was surprisingly small in the E9018 weld metal tested. The reduction encountered in Test H was the greatest—6800 psi. Even the decrease in tensile strength was not generally substantial.

Referring to Fig. 2, the tensile bars by virtue of their location in the joint, contained very little base metal dilution or enrichment. In view of this, the magnitude of the variation in yield strength here encountered should generate concern over the actual yield strength level of weld metal in highly diluted areas—root passes, for instance—in restrained joints in higher carbon or higher alloy base metals, such as HY-80 and "T" Steel.

Conclusions and Recommendations

This study of the effect of welding variables on the yield strength of certain low-alloy steel weld metal indicates that:

1. The strength of a welded joint depends, in addition to other factors, on the specific detailed manner in which the weld metal is actually deposited in that joint.

2. A given electrode, classified as E9018 in accordance with the provisions of existing specifications, may deposit weld metal during fabrication which will have as-welded tensile properties of an E9018, E10018 or possibly even an E11018 electrode, depending on how the electrode is applied. Stringer beads and low preheat and interpass temperature give the highest strength weld metal.

3. Specification procedures and techniques governing manufacturing tests of electrodes, user inspection tests and subsequent fabrication procedures must be identical if reasonable reproduction of results is to be expected.

4. Attempts to correlate weld metal mechanical properties with the amount or location of fabrication cracking difficulties must be made on the basis of actual joint weld metal properties and not on the manufacturer's lot inspection test results, unless the two are actually made in the same fashion (see Table 5). Moreover, in single-pass fillets and root-pass work the effect of dilution, in addition to the effect of welding technique, should not be overlooked.

5. Where higher strength welds are desired, consideration should be given to the use of stringer bead techniques, and lower preheat and interpass temperature levels.

A Method of Determining Primary Solid Solubility of an Alloy

BY F. N. ADGATE

One of the causes of trouble in welding high temperature alloys is eutectic phases that have a lower melting point than the base metal. This is also true of high temperature brazing alloys, mainly in the Cr-Ni-Fe-B series. These lower melting eutectics are caused generally by a lack of primary solid solubility of one or more elements in the base metal. This paper presents one tentative method of checking the primary solid solubility of an alloy prior to its use.

A primary solid solution can be defined as a homogeneous alloy having the same crystal structure as the parent metal. An interstitial solid solution is formed when one atom of a metal element is much smaller than the base metal atom. As an example of this, the solution of carbon in austenite iron where the carbon atom diameter is 1.5 and the iron atom diameter is 2.481 to 2.585. In this case the carbon atom will form an interstitial solid solution in the iron lattice. The work of Hume-Rothery and A. H. Cottrell has shown that the formation of primary solid solutions is affected by three values, listed in their order of importance:

A. Size factor of the atoms.
B. Electro-chemical compounds.
C. Electron compounds or valency.

In reference to the size factor of the atoms, an increasing difference in the diameters of the solute and solvent atoms decreases the range of primary solution. If the diameters differ by more than 15% of that of the solvent, the solubility is small. This can be expressed in graph formation as shown in the following example of copper. The diameter of copper is 2.54. Fifteen percent of this figure is 0.38 Therefore, the range of solid solubility will be from 2.16 to 2.92. If this is plotted on a graph and the atomic diameters of the metals that are alloyed with copper are plotted on the same graph, any element whose atomic diameter falls within 2.92 and 2.16 will probably form a solid solution with copper. When the metal falls outside these favorable limits, there is a marked increase in the difficulty with which the atoms will fit together on a common lattice.

In reference to the second factor of electro-chemical compounds, it can be stated that the more electro-positive the one component and the more electro-negative the other, the greater is the tendency to form intermetallic compounds rather than wide solid solutions. This leads to a small primary solid solubility.

In regard to the third factor of electron compounds or valency, a metal of lower valency is liable to dissolve one of the higher valency than vice versa, other things being equal. This is valid mainly for alloys of copper, gold, silver, with those of higher valency.

As in every theory there are some variations. Due to the small size of the atoms, hydrogen, boron, nitrogen and oxygen will usually form interstitial solid solutions whereas most metallic elements

(*Continued on page 222-s*)

F. N. ADGATE is a welding engineer with Lockheed Aircraft, Burbank, Calif.

Mechanical Properties of Molybdenum Welds Below 700° F

Molybdenum welds made in a dry box with the tungsten-arc process are investigated for service as a container material in the Liquid Metal Fuel Reactor

BY R. E. PAVLAK, M. CHRISTENSEN AND A. L. LOWE, JR.

ABSTRACT. Molybdenum - to - molybdenum and molybdenum-to-steel welds were investigated over the temperature range from room temperature to 700° F. Welds were made in sheet material, and the strength and ductility properties were evaluated. The tensile strength of the welded specimens was about one-half that of the base metals; ductility was low at room temperature but increased slightly as the temperature approached 700° F.

Examination of the weld metal from each test revealed no porosity or microcracking. However, the molybdenum-to-steel joint was not a fusion weld but was more similar to a high temperature braze as the molybdenum did not melt during welding.

Introduction

Molybdenum-to-molybdenum (Mo-Mo) and molybdenum-to-steel (Mo-steel) joints for service to 700° F became a development problem during the Liquid Metal Fuel Reactor (LMFR) design. Molybdenum has excellent corrosion resistance to liquid bismuth and, as a result, was a highly desirable container material for LMFR use. Molybdenum's high cost limited its extensive use, so other materials were specified where possible. Thus two types of joints were required—Mo-Mo and Mo-steel.

The low strength requirements for these joints increased the probability of finding a satisfactory joining procedure. The Mo-steel joint would not be exposed to liquid bismuth; therefore, a leaktight joint would be satisfactory. The Mo-Mo joint would not carry an appreciable load or be subjected to impact; thus again, any sound leaktight weld should be satisfactory. In addition, the room temperature properties were not of prime importance, because the joints would normally operate at 500 to 700° F. As a result, it was believed that the joints would have better impact and ductility properties at service temperatures than at room temperature.

A review of the literature[1-16] indicated that molybdenum could be joined successfully by fusion welding methods provided proper conditions are maintained. In part, this success may be attributed to recent developments in the production of high-purity arc cast molybdenum which reduced porosity during welding while maintaining good physical properties.

A welding program was conducted to investigate the feasibility of making sound molybdenum to molybdenum and molybdenum to $2^1/_4$Cr – 1Mo steel welds. A second objective of this study was to establish the physical properties of these welds from room temperature to 700° F.

Materials

In this investigation $^1/_{16}$-in. thick molybdenum and molybdenum alloyed with $^1/_2$% Ti were supplied and used in the hot cross-rolled (1850° F) condition. No commercial mill analysis was supplied.

The $^1/_8$-in. thick steel sheet and filler wire were used in the normalized (1750° F/AC) and stress relieved (1225° F) condition. The following general mill analysis was provided for $2^1/_4$ Cr – 1Mo steel: C, 0.15% (max); Mn, 0.3 to 0.6%; Si, 0.50% (max); Cr, 2.0 to 2.5%; Mo, 0.9 to 1.1%.

Argon shielding gas utilized during welding was of commercial welding grade.

Procedures

Specimen Preparation

Test plates $1^1/_2$-in. wide by 6-in. long were cut from $^1/_{16}$-in. thick molybdenum plate and $^1/_8$-in. thick $2^1/_4$Cr – 1Mo steel plate to form a 3- x 6-in. welded test plate. Ten tensometer test specimens were obtained from each test plate to provide duplicate samples over the explored test temperature range from one weld. Each tensile specimen was 3 in. long and $^1/_2$ in. wide with a reduced section 2 in. long and $^1/_4$ in. wide. The elongation was measured over a 2-in. long gage length.

Cleaning

Before welding, the molybdenum and molybdenum plus $^1/_2$% Ti test plates were cleaned of grease and surface oxide using the Ryan cleaning method. This method is described as follows:

1. Immerse material in a solution of 10 parts NaOH, 5 parts $KMnO_4$ and 85 parts H_2O, for 10 min at 180° F and rinse in water.
2. Remove the black surface film remaining after rinsing in water by rinsing in a solution of 15 parts H_2SO_4, 15 parts HCl, 70 parts H_2O and 10% wt by vol Cr_2O_3.

The edge of the steel test plates to be welded was cleaned by belt grinding and washing in acetone.

Welding

Molybdenum welding was accomplished in a dry-box under an inert atmosphere of argon. The drybox was first evacuated to $^1/_{10}$ micron and filled with argon gas at one atmosphere pressure. Plate sections to be welded were posi-

All three authors are with the Babcock & Wilcox Co. R. E. PAVLAK and M. CHRISTENSEN are at the Research Center, Alliance, Ohio; A. L. LOWE, JR., is with the Atomic Energy Div., Lynchburg, Va.

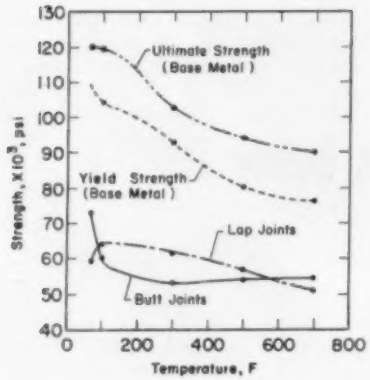

Fig. 1—Comparison of the ultimate strength of butt and lap joints (Mo-Mo welds) with the ultimate and yield strength of the base material as a function of temperature

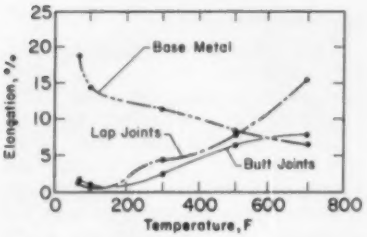

Fig. 2—Comparison of the ductility of butt and lap joint (Mo-Mo welds) with the base material as a function of temperature

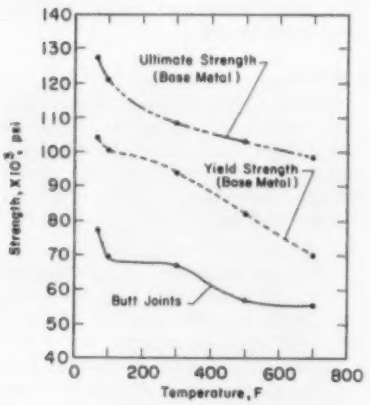

Fig. 3—Comparison of the ultimate strength of butt joint (Mo + $^1/_2$Ti welds) with the ultimate and yield strengths of the base metal as a function of temperature

tioned securely on a copper backing plate by means of "C" clamps. Welding was carried out using the tungsten-arc inert-gas shielded process. Side-ports in the lower half of the drybox permitted operator manipulation of the torch during welding. Power was supplied by motor-generator type d-c welder rated at 30 to 360 amp.

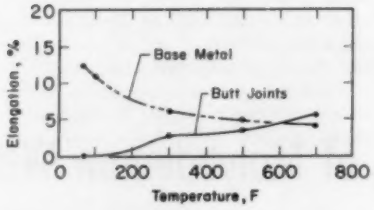

Fig. 4—Comparison of the ductility of butt joint (Mo + $^1/_2$Ti welds) with the base material as a function of temperature

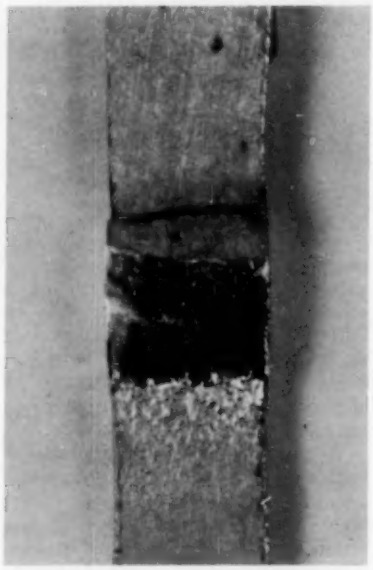

Fig. 5—Photograph of Mo-Mo lap welded tensile specimen tested at 700° F showing ductility characteristics of necking and metal distortion in the weld heat-affected zone

After properly aligning and positioning the two halves of the test plate, the copper backing plate was preheated to 500° F with the tungsten-arc torch. The temperature was measured by means of a temperature-indicating crayon. After welding, the test specimen was allowed to cool to approximately 500° F in the inert atmosphere to prevent excessive oxidation of the molybdenum upon removal.

D. Mechanical Testing

Room and elevated temperature tensile tests were conducted on a Hounsfield tensometer which is specially adapted to testing thin-walled specimens. A 6-in. high-resistance element furnace connected to a variable resistance was used to provide heat for the elevated temperature tests. Because of the low temperatures involved, the furnace zone was not purged with inert gas during testing. All pertinent physical data were obtained from stress-strain curves drawn on a rotating drum chart.

Results

Base Material

The room and elevated temperature (up to 700° F) strength and ductility properties of molybdenum and molybdenum alloyed with $^1/_2$% Ti are graphically illustrated in Figs. 1 through 4. All specimens were tested in the direction parallel to the final rolling direction.

Molybdenum alloyed with $^1/_2$% Ti showed higher tensile strength than the unalloyed molybdenum over the explored temperature range, particularly at temperatures above 300° F. An unexpected decrease in ductility was observed in both materials up to the maximum test temperature.

Molybdenum-to-Molybdenum Welds

Initial welds made with test plates restrained directly on the copper backing plate exhibited extensive cracking in the weld crater and heat-affected zone. The alloyed molybdenum appeared more sensitive to cracking than the unalloyed molybdenum. It was found that elevating the test plate $^1/_{16}$ in. above the preheated copper backing plate reduced sensitivity toward cracking in both materials. Further modifications such as accelerating the welding speed and welding in one pass, where possible, completely eliminated further cracking in molybdenum. Although substantially reduced, erratic cracking was still encountered in welding the alloyed material.

The ultimate strength of molybdenum and molybdenum plus $^1/_2$% Ti welded joints was approximately one-half that of the base material at room temperature. The decrease in strength of the welded joints was considerably less than that of the base material across the explored temperature range. Butt welds were, in general, stronger than lap welds at the lower test temperatures, the difference decreasing with higher temperatures. Molybdenum plus $^1/_2$% Ti joints exhibited greater strength than molybdenum joints.

None of the above weld joints showed any appreciable room temperature ductility. A slight increase in ductility was observed at the 300° F test temperature. From 300° up to 700° F. the ductility in welded joints of both materials increased rapidly to a maximum elongation of 15.5% in molybdenum-to-molybdenum lap joints and 8% for butt joints.

The elongation occurring in the more ductile welded joints was confined to the heat-affected zone on

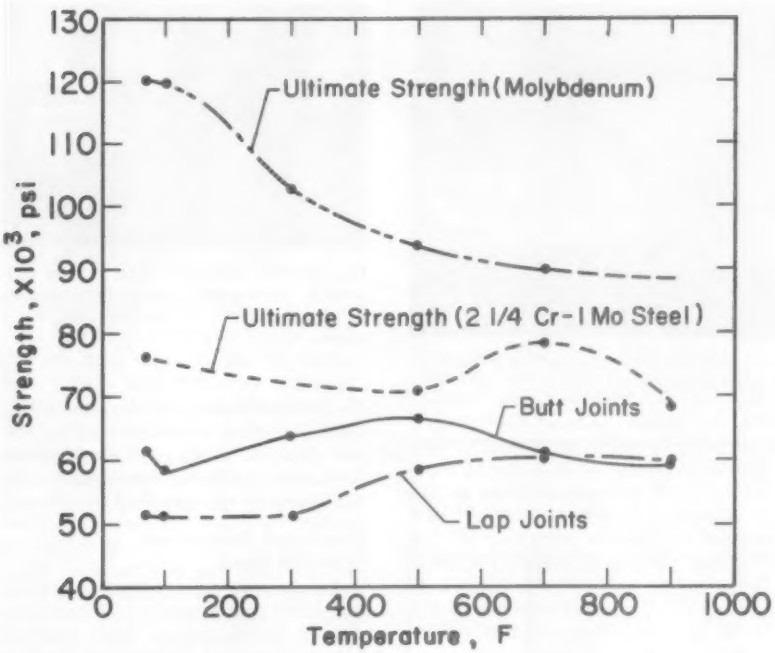

Fig. 6—Comparison of the ultimate strengths of butt and lap joint (Mo to $2^1/_4$Cr-1Mo welds) with the ultimate and yield strengths of the base material as a function of temperature

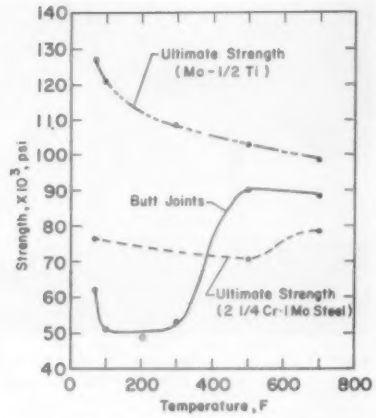

Fig. 8—Comparison of the ultimate strengths of butt joint (Mo + $^1/_2$Ti to $2^1/_4$ Cr-1 Mo Welds) with the ultimate strength of the base material as a function of temperature

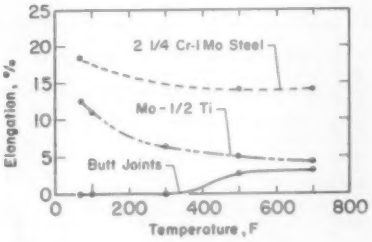

Fig. 9—Comparison of the ductility of butt joint (Mo + $^1/_2$Ti to $2^1/_4$Cr–1 Mo welds) with the base material as a function of temperature

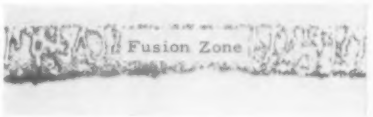

Fig. 10—Intermetallic fusion zone between molybdenum and $2^1/_4$Cr–1Mo weld metal

both sides of the welded joint. This is illustrated in Fig. 5 showing a molybdenum-to-molybdenum butt joint tested at 700° F. An explanation for this phenomena is presented in the discussion.

Molybdenum-to-steel Welds

The mechanical properties of molybdenum-to-steel welds are shown in Figs. 6 and 7. Less cracking difficulty was experienced with Mo-steel welds than comparable molybdenum-molybdenum welds. Because of the wide difference in the melting points of the two materials ($2^1/_4$ Cr - 1Mo steel 2650° F; molybdenum—4750° F) lower welding temperatures were required, thereby reducing crack sensitivity. The joint was not a fusion weld but was more similar to a high temperature braze as the molybdenum was not melted during welding.

Unalloyed molybdenum-to-steel butt and lap joints showed little variation in ultimate strength from room temperature to 900° F. At test temperatures up to 500° F, failure occurred in the molybdenum heat-affected zone near the dissimilar metal interface. These failures occurred with no measurable joint ductility. Failure at the 700 and 900° F test temperature levels occurred as a clean separation directly at the dissimilar metal interface. Butt welds again showed almost negligible ductility. Lap welds increased to approximately 5% elongation at 900° F.

Molybdenum – $^1/_2$% Ti to steel butt joints showed a large increase in tensile strength from room temperatures to 700° F as shown in Fig. 8. The ductility of this type joint ranged from negligible at the lower test temperature to 3.0% at 700° F as shown in Fig. 9.

This increase in tensile strength with increasing test temperature indicates that some degree of alloying between the alloyed molyb-

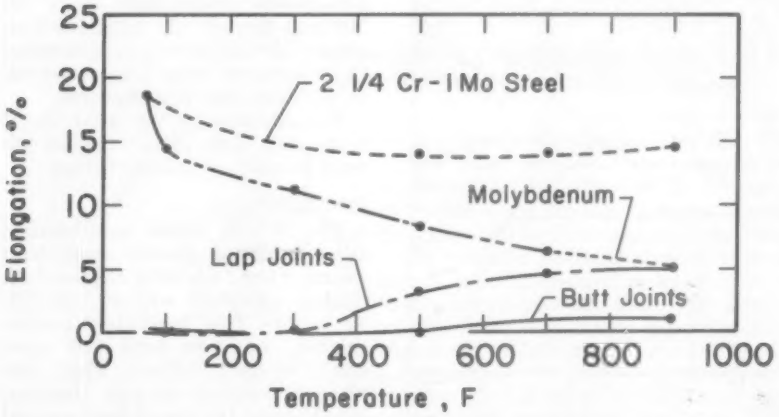

Fig. 7—Comparison of the ultimate strengths of butt joint (Mo + $^1/_4$Ti to $2^1/_4$Cr–1 Mo welds) with the ultimate strength of the base material as a function of temperature

Fig. 11—Photomicrograph of Mo-Mo butt joint showing the grain coarsening in the weld metal and location of failure in the weld heat-affected zone

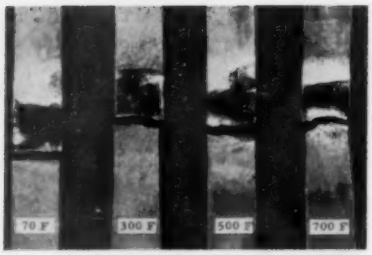

Fig. 12—Heat-affected zone tensile failures in Mo-Mo welds (note the increase in ductility with increasing test temperature)

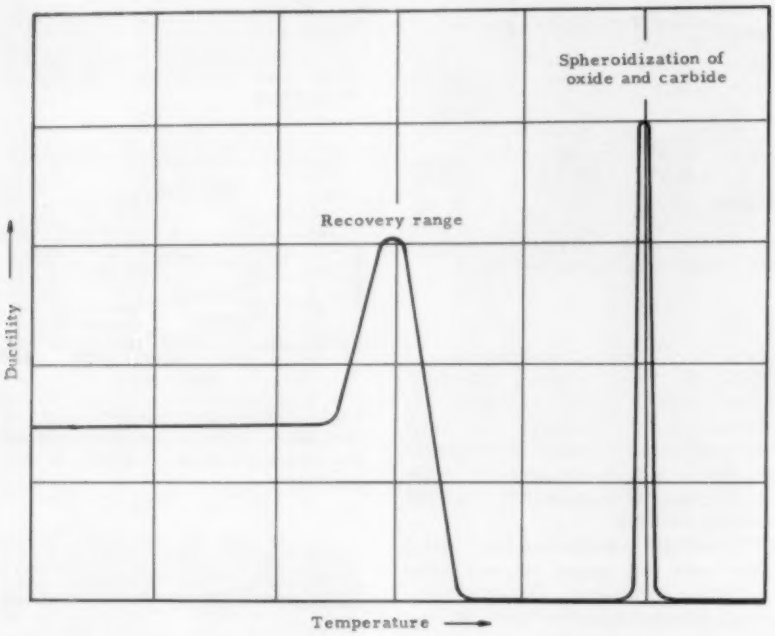

Fig. 13—Effect of annealing temperature on the ductility of molybdenum[1]

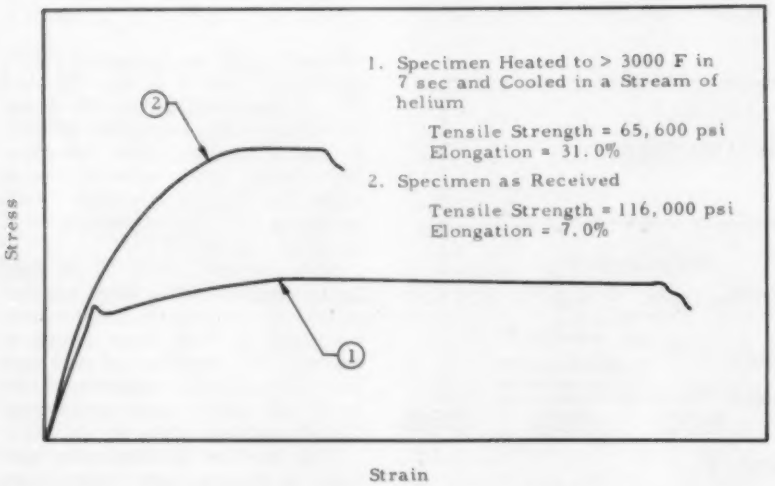
1. Specimen Heated to > 3000 F in 7 sec and Cooled in a Stream of helium
Tensile Strength = 65,600 psi
Elongation = 31.0%
2. Specimen as Received
Tensile Strength = 116,000 psi
Elongation = 7.0%
2
1
Stress
Strain

Fig. 14—Effect of special heat treatment on the mechanical properties of molybdenum

denum and steel may have occurred. This is further substantiated by the fact that all failures in these joints occurred outside the dissimilar metal interface in the heat-affected zone.

Microscopic Examination of Welded Joints

Microscopic examination revealed extensive grain growth in the molybdenum weld metal and heat-affected zone as illustrated in Fig. 10. The low ductility experienced in molybdenum welds made by the nonconsumable inert-gas electrode welding technique has been attributed by many investigators to the growth of large grains. The prospect of obtaining a ductile room temperature molybdenum weld by any fusion method seems remote at present.

In joining molybdenum to steel, only slight penetration has been observed in the molybdenum base metal as illustrated in Fig. 11. This is typical of dissimilar joints that are made between materials with a great difference in melting points. As shown in Fig. 11, the steel weld metal has alloyed with enough molybdenum to resist etching. Also illustrated is the weld metal-molybdenum interface consisting of an unidentified, deeply etched molybdenum-steel intermediate alloy. At 700 and 900° F the tensile failure occurs at this interface, indicating the interfacial alloy loses strength at relatively low temperatures.

Examination of the weld metal from each test plate revealed no weld porosity or microcracking.

Bend Tests

The $^1/_{16}$-in. thick molybdenum sheet exhibited greater room temperature bend ductility than molybdenum alloyed with $^1/_2$% Ti. In a slow free bend test molybdenum could be bent flat upon itself without failure while the alloyed material cracked after approximately 150 deg of bend around a $^1/_4$-in. radius. A considerably greater difference occurred when

specimens of both materials were bent under impact. Molybdenum again was successfully bent upon itself, while the alloy material fractured after only slight bending.

Welded joints of both materials showed no room temperature bend ductility in a slow free-bend test. Application of a bending force caused immediate failure in the heat-affected zone.

Discussion of Results

It has been observed that molybdenum plus 1/2% Ti joints become less brittle and undergo some deformation in the neighborhood of 300° F. Further increase of temperature results in a gradual improvement in ductility up to 700° F. At this temperature the increase becomes more marked, particularly in lap joints.

All measurable ductility in the welded specimens appears to have occurred in the base metal heat-affected zone, particularly so in the tensile specimens tested at 700° F. Figure 12 shows this elongation and the reduction in area. The maximum deformation appears to have occurred in an area that was heated to some critical annealing temperature during welding and then rapidly cooled. The ductile zones in the base metal which appear on either side of the weld attain a maximum ductility in some band of the heat gradient which has had a favorable time-temperature heat treatment. Figure 13, a schematic diagram of molybdenum ductility vs. heat treatment temperature,[1] suggests an explanation for the localized deformation. Visual and microscopic observations did not show deformations in the weld metal adjacent to the ductile zones.

As a result of these observations, four specimens from a lot of low-ductility molybdenum were tested. Each specimen was resistance-heated to a high temperature (3000° F) in a very short time (<7 sec) and then rapidly cooled in helium. Figure 14 shows the results of this heat treatment on the mechanical properties of the as-received molybdenum. The tensile strength dropped from 116,000 psi for the as-received material to 65,600 psi for the heat-treated material. Correspondingly, the elongation increased from 7 to 31%.

The complete lack of ductility shown by Mo-Mo joints at the lower test temperatures was apparently related to the eccentricity of the welded specimens. The extent of eccentricity inherent in welded members was shown by the wide variations in tensile strength of a welded specimen at any constant test condition.

The brittle tensile failures in or near the weld junction (below 300° F) can be attributed to misalignment stresses at that location. At the higher test temperature (500 to 700° F), some softening occurred in the molybdenum-base metals. This, combined with the increased ductility in the favorably annealed region of the heat-affected zone, permitted the misalignment to be corrected at a lower stress and the welded specimen showed a significant elongation. Considering the breaking load, it is probable that all elongation occurred in the ductile area of the heat-affected zone.

Acknowledgment

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References

1. Northcott, L., "The Joining of Molybdenum," *Molybdenum*, Butterworth's Scientific Publications, 190–220 (1956).

2. Johnson, J. H., Udin, H., and Wulff, J., "Joining of Molybdenum," THE WELDING JOURNAL, **33** (9), Research Suppl., 449-s to 458-s (1954).

3. Bechtold, J. H., "Recrystallization Applied to Control of Mechanical Properties," *Trans. Am. Soc. Metals*, **46**, 1449 (1954).

4. Case, S. L., "Summary Report on a Metallurgical Study of Molybdenum," Battelle Memorial Institute Report to the Office of Naval Research, Navy Department (Contract No. N9onr 82100), Oct. 15, 1954.

5. Bechtold, J. H., and Wessel, E. T., "Ductile-to-Brittle Transition in Molybdenum," *The Metal Molybdenum*, American Society for Metals, Cleveland, Ohio, 241–261 (1958).

6. "Found Deoxidizing Process to Clean Molybdenum for Welding," *Western Metal*, **15**, 12, 61–62 (1957).

7. Platte, W. N., "Welding of Molybdenum," *The Metal Molybdenum*, American Society for Metals, Cleveland, Ohio, 151–191 (1958).

8. Platte, W. N., "Influence of Oxygen on the Soundness and Ductility of Molybdenym Welds," THE WELDING JOURNAL, **35** (8) Research Suppl., 369-s to 381-s (1956).

9. Platte, W. N., "Effect of Nitrogen on the Soundness and Ductility of Molybdenum Welds," *Ibid.*, **36** (6), Research Suppl., 301-s to 306-s (1957).

10. Weare, N. E., Monroe, R. E., and Martin, D. C., "Ductility of Tungsten-Arc Welds in Molybdenum," *Ibid.*, **36** (6), Research Suppl., 291-s to 300-s (1957).

11. Monroe, R. E., Weare, N. E., and Martin, D. C., "Fabrication and Welding of Arc-Cast Molybdenum," *Ibid.*, **35** (10), Research Suppl., 488-s to 498-s (1956).

12. Weare, N. E., Monroe, R. E., and Martin, D. C., "Inert-Gas-Shielded Consumable-Electrode Welding of Molybdenum," *Ibid.*, **37** (3), Research Suppl., 188-s to 124-s (1958).

13. Platte, W. N., "Joining of Molybdenum," WADC Technical Report 54-17, Parts 1, 2, and 3 (November 1956).

14. Platte, W. N., "Joining of Molybdenum," WADC Technical Report 57-309 (August 1957).

15. Kulju, K. M., and Kearns, W. H., "Welding Molybdenum Alloy Sheet," THE WELDING JOURNAL, **37** (10), Research Suppl., 440-s to 444-s (1958).

16. Goodman, I. S., "Arc Welding of Molybdenum." *Ibid* .., **29** (1), 37-44 (1950).

WRC Bulletin No. 67

Strength of Thick-Walled Cylindrical Vessels Under Internal Pressure for Three Steels

Welding Research Council Bulletin Number 67, published in March 1961, describes a phase of the current research Project being sponsored by the Pressure Vessel Research Committee of the Council. This Project is being carried out at Pennsylvania State University under the direction of Professor J. Marin and under the guidance of the Subcommittee on Pressure Vessel Shell Theory. This is the third of a series of Bulletins dealing with the prediction of the maximum internal pressure that can be applied to thick-walled cylindrical vessels. The determination of the maximum pressure that a pressure vessel can withstand is of considerable importance in design. This report gives results for three pressure vessel steels designated as: A212 Grade B Firebox Quality, A285 Grade C Firebox Quality and T304 Stainless.

The price of this Bulletin is $1.00 and single copies may be purchased through the American Welding Society, 33 West 39th Street, New York 18, N. Y. Quantity lots may be purchased through the Welding Research Council, 29 West 39th Street, New York 18, N. Y.

On Notch Sensitivity

Observation of a defect in a welded structure leads to experimentation in aluminum wherein the behavior of notched sections is related to the fully-plastic theory

BY F. A. McCLINTOCK

ABSTRACT. A discussion of the need for considering the ductility of structures leads to the definition of both load and deformation factors relating the actual behavior of notched sections to that predicted by plasticity theory for fully ductile materials. Experiments on pure aluminum are in agreement with the fully-plastic theory. Experiments on 7075 aluminum alloy and 4140 steel show a notch sensitivity, with a crack behavior and size effect similar to that predicted from elastic-plastic analysis.

Introduction

One of the problems for which the designer has few quantitative tools available is that of the design of a structure for given load-carrying and ductility requirements even in the presence of sharp notches, cracks or possible defects in the material.

An illustration of this type of problem, especially in connection with ductility requirements, is given by a failure which occurred in a tube serving as the tension member of a main spar of an internally-braced, cantilever-winged monoplane. The tube was welded to a fish tail connector, as shown in Fig. 1. The abrupt change in cross section led to a faulty weld underneath the surface so that a re-entrant crack was formed. Of course, a more gradual change in section would have allowed the fish-tail connector to be heated as quickly as the tube in the region where the weld was first made and would have prevented this sharp notch. However, in this case the part was made as shown, proof tested, and found able to carry the designed ultimate load.

Later, the airplane fell apart in the air, and the question arose as to whether failure was due to fatigue or to an overload due to gust or maneuver. The shear-type fracture indicated either overload or low-cycle fatigue, but plastic deformation in the eye pointed to an overload. There was little if any over-all deformation; in fact, the length of the tube was still within the design tolerance. The *material* had all the ductility which would be expected of it, as shown by the shear fracture and by tests on strips cut from the tube. But the *structure* was almost as brittle as glass. Had there been over-all deformation of the main spar before fracture, the gust might have been passed or the pilot might have had time to recover from a maneuver.

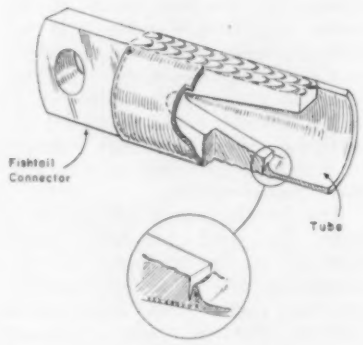

Fig. 1—Internally-notched tube

Sometimes, then, one would like to ensure that the ductility of the material which one would expect from the tensile test is actually available in the structure. This will be so if the load-carrying capacity of the section containing the notch (or a possible notch) is greater than the load required to produce general yielding elsewhere in the structure. In redundant structures, relatively little deformation of one member may be required before other members attain their ultimate loads. In such cases the ductility in the immediate vicinity of the notch may be enough. The designer needs quantitative information on the load-carrying capacity and possible deformation of various kinds of notches in different materials. It is the purpose of this paper to define performance factors which the materials tester can use to report to the designer how actual metals deviate from the current theory. The results of some experiments will be discussed in the light of these performance factors.

Load and Deformation Factors for Notches

For a complete description of the behavior of a notched specimen from the structural point of view, a load-deformation diagram would be required, such as that shown in Fig. 2 for a ductile material. Cracking may begin either before or after the point of maximum load, and the decrease in load beyond the maximum is due to the reduction of area by cracking, plastic flow or both. Since the maximum load occurs at a deformation small compared to the final deformation, the main features of the diagram are given by the maximum load and the final deformation. As less ductile materials are considered, the final deformation is reduced without change in maximum load, while for still less ductile materials the load will also be re-

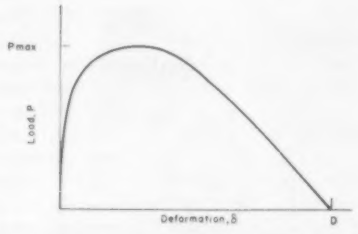

Fig. 2—Load-deformation plot for a fully-ductile specimen

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duced. Thus two parameters, one dealing with the maximum load and the other with the final deformation, summarize the performance of a notched section.

For convenience, the performance of a section of material containing a notch will be compared to some standard. In the past, the standard of load-carrying ability has been simply the tensile strength multiplied by the net area at the root of the notch. There has been no standard index of deformation of a notched member. In recent years the theory of plastic, nonstrain-hardening materials has been developed to the point where it can provide a definite estimate of the load-carrying ability and a tentative estimate of the final deformation of many kinds of notched sections. It is proposed that these results now be used as a standard with which the actual behavior of notched specimens is to be compared. The term "standard" rather than "theoretical" is used, because it is to be hoped that a theoretical prediction of notch sensitivity itself will some day be possible. In that event, the "theoretical" performance will be different from the "standard" performance. The term "ideal" is avoided because ever greater load carrying capacity and deformation are desirable and may even be attained in a strain-hardening material.

The load and deformation factors of notched sections are now defined as follows:

$$\text{load factor } (F_L) = \frac{\text{actual maximum load}}{\text{standard maximum load}} \quad (1)$$

$$\text{deformation factor } (F_D) = \frac{\text{actual final deformation across the notch}}{\text{standard final deformation}} \quad (2)$$

Standard Load and Deformation of Various Notches

Existing theoretical solutions require the assumption of a rigid-plastic, nonstrain-hardening material. The neglect of elastic strain is reasonable in an ideally ductile material where fracture occurs not by cracking but by progressive necking down of the material, with accompanying large strains. To approximate a strain-hardening material by an ideally plastic one, a stress should be chosen higher than the yield stress of the material, but below the true fracture stress of a tensile specimen, since the net area of the notch will be decreased appreciably before frac-

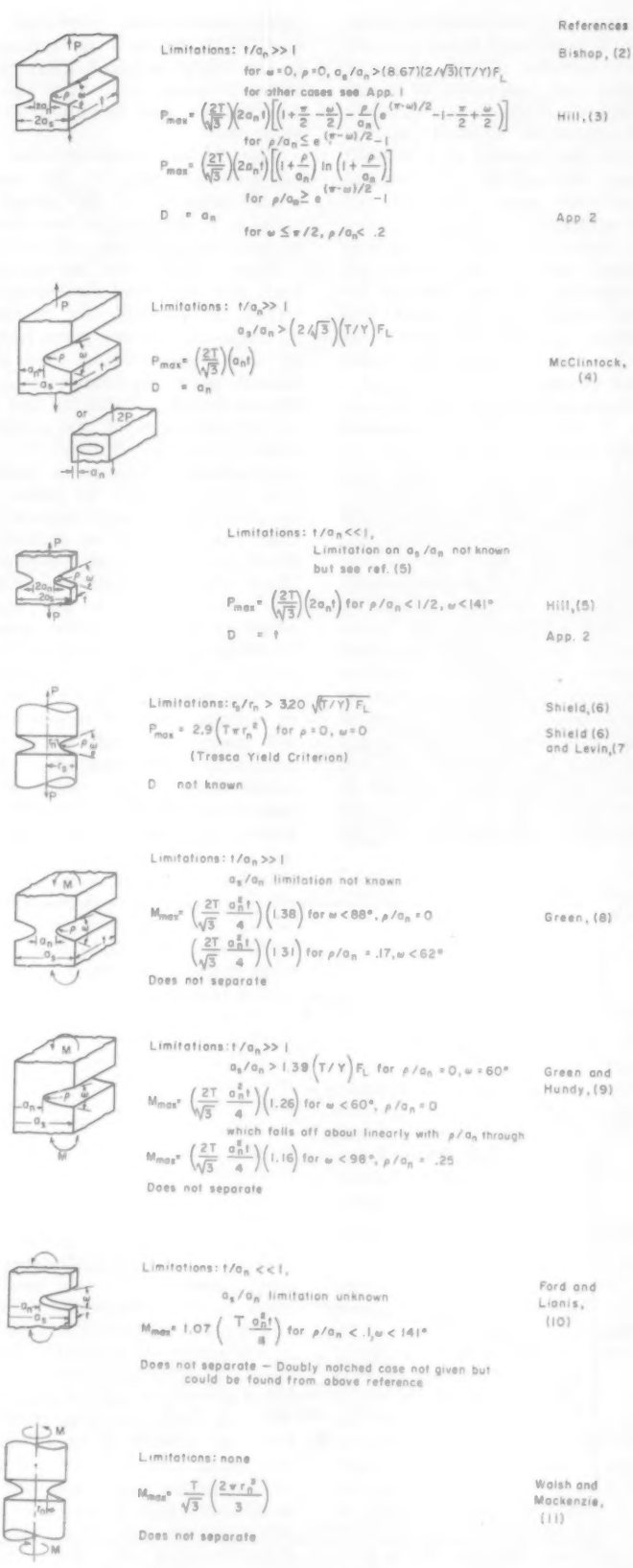
References
Limitations: $t/a_n \gg 1$
for $\omega = 0$, $\rho = 0$, $a_s/a_n > (8.67)(2/\sqrt{3})(T/Y)F_L$
for other cases see App. 1
$P_{max} = \left(\frac{2T}{\sqrt{3}}\right)(2a_n t)\left[\left(1+\frac{\pi}{2}-\frac{\omega}{2}\right)-\frac{\rho}{a_n}\left(e^{(\pi-\omega)/2}-1-\frac{\pi}{2}+\frac{\omega}{2}\right)\right]$
for $\rho/a_n \leq e^{(\pi-\omega)/2}-1$
Bishop, (2)
Hill, (3)
$P_{max} = \left(\frac{2T}{\sqrt{3}}\right)(2a_n t)\left[\left(1+\frac{\rho}{a_n}\right)\ln\left(1+\frac{\rho}{a_n}\right)\right]$
for $\rho/a_n \geq e^{(\pi-\omega)/2}-1$
$D = a_n$
for $\omega \leq \pi/2$, $\rho/a_n < .2$
App. 2
Limitations: $t/a_n \gg 1$
$a_s/a_n > \left(2\sqrt{3}\right)\left(T/Y\right)F_L$
$P_{max} = \left(\frac{2T}{\sqrt{3}}\right)(a_n t)$
$D = a_n$
McClintock, (4)
or
Limitations: $t/a_n \ll 1$,
Limitation on a_s/a_n not known
but see ref. (5)
$P_{max} = \left(\frac{2T}{\sqrt{3}}\right)(2a_n t)$ for $\rho/a_n < 1/2$, $\omega < 141°$
Hill, (5)
$D = t$
App. 2
Limitations: $r_s/r_n > 3.20\sqrt{(T/Y)F_L}$
$P_{max} = 2.9\left(T\pi r_n^2\right)$ for $\rho = 0$, $\omega = 0$
(Tresca Yield Criterion)
D not known
Shield, (6)
Shield (6) and Levin, (7)
Limitations: $t/a_n \gg 1$
a_s/a_n limitation not known
$M_{max} = \left(\frac{2T}{\sqrt{3}}\frac{a_n^2 t}{4}\right)(1.38)$ for $\omega < 88°$, $\rho/a_n = 0$
$\left(\frac{2T}{\sqrt{3}}\frac{a_n^2 t}{4}\right)(1.31)$ for $\rho/a_n = .17$, $\omega < 62°$
Does not separate
Green, (8)
Limitations: $t/a_n \gg 1$
$a_s/a_n > 1.39\left(T/Y\right)F_L$ for $\rho/a_n = 0$, $\omega = 60°$
$M_{max} = \left(\frac{2T}{\sqrt{3}}\frac{a_n^2 t}{4}\right)(1.26)$ for $\omega < 60°$, $\rho/a_n = 0$
which falls off about linearly with ρ/a_n through
$M_{max} = \left(\frac{2T}{\sqrt{3}}\frac{a_n^2 t}{4}\right)(1.16)$ for $\omega < 98°$, $\rho/a_n = .25$
Does not separate
Green and Hundy, (9)
Limitations: $t/a_n \ll 1$,
a_s/a_n limitation unknown
$M_{max} = 1.07\left(T\frac{a_n^2 t}{8}\right)$ for $\rho/a_n < .1$, $\omega < 141°$
Does not separate – Doubly notched case not given but could be found from above reference
Ford and Lianis, (10)
Limitations: none
$M_{max} = \frac{T}{\sqrt{3}}\left(\frac{2\pi r_n^3}{3}\right)$
Does not separate
Walsh and Mackenzie, (11)

Fig. 3—Standard maximum load and final deformation. Ductile material with tensile strength T and yield strength Y

ture occurs. An intermediate value, which in a crude way takes account of the combined effects of strain hardening and reduction of cross-sectional area, is the tensile strength of the material, defined as the maximum load carried by a smooth specimen divided by the original cross-sectional area. Use of the tensile strength in idealizing the actual behavior has the added advantage that the tensile strength is a commonly known quantity for a wide variety of materials and one which a designer would be likely to use in estimating load-carrying capacities.

As discussed below and in Appendix A, it will further be assumed that the notch is deep enough so that all deformation occurs near the notch.

Finally, the cases considered will be idealized into ones of either plane strain or plane stress. For plane strain, the specimen must be like a plate with grooves in the faces. For plane stress the thickness of the specimen must be small compared to the radius of curvature of the notch. Thus it is impossible for a specimen with a *sharp* notch to be subjected to strictly plane stress. But Drucker[1] has pointed out that the load-carrying capacity of a sharply notched specimen may be closely approximated by the plane stress case, provided only that the thickness is small compared to the width of the minimum section. It seems likely that the final deformation can be found in the same way.

The Mises yield criterion will be used so that, if the uniaxial tensile strength of the actual material is T, the yield of the idealized material in pure shear will be $T/\sqrt{3}$.

Figure 3 presents the maximum load and the final deformation is found theoretically for a variety of cases. Loads are given in terms of the corresponding load for a smooth plate multiplied by a constraint factor. Values of the loads are sometimes exact, and sometimes approximate to within 2% if only approximate solutions are known or if a larger variety of cases could be fitted by an approximate equation. In bending or torsion, the theory does not predict separation. Thus the deformation factor for any material which did fracture would be zero. In these cases, the ductility can best be described by giving an angle of bending or twisting directly. Even in the case of tension, the final deformation is not known theoretically for the doubly-notched specimen, pending application of the recent uniqueness theorems of Hill.[12] The estimates for this case are discussed in Appendix B and are probably no better than ±20%.

Figure 3 contains several noteworthy results. Very large shoulders are required to confine deformation to the root of the notch in the case of tension of either circumferentially notched or plane strain, doubly-grooved specimens. Secondly, although the load-carrying capacity of the doubly-grooved plane strain case can be $2^1/_2$ times that for a smooth specimen in plane strain, the load-carrying capacity of the singly-grooved plane strain specimen is just equal to that of a smooth specimen. In fact, even the local stress at the root of the groove is no higher than for a smooth specimen subjected to plane strain. Finally, Green[8] has shown that, although the bending moments in the plane-strain case are not much above those of smooth specimens, the triaxiality near the root of the groove may be almost as high as in the case of the doubly-grooved tensile specimen.

Experimental Observations

7075 Aluminum Alloy, Varying Groove Angle

In the first series of tests, the effects of groove angle and groove radius were observed in 7075 aluminum-zinc alloy in the form of a $^1/_4$ x $^3/_4$ in. bar, both in the T6 condition and as annealed by holding at 815° F for 2 hr., air cooling, heating to 450° F for 4 hr, and finally furnace cooling. Tensile tests were run on 1-in. gage length, $^1/_4$-in. diam specimens machined from the ends of the grooved specimens, giving the results shown in Fig. 4. The fracture surfaces were somewhat irregular and were oblique rather than normal to the axis of the specimen.

To produce conditions of nearly plane strain, grooves were cut in the faces of the strip as shown in Fig. 5. The width of the strip was chosen large enough so that edge effects would not be likely to amount to more than a few percent in the estimation of the standard load. One groove angle was held constant at 30 deg while the other was varied. Thus the more obtuse angle determined the slip-line field as shown in Fig. 6, while the 30 deg groove assured a strain concentration.

The ratio of shoulder to minimum thickness of 5 to 1 was chosen without knowing just what ratio would be required to prevent flow from breaking out at the shoulder. It was found that the shoulder thinning was 0.04% or less whenever

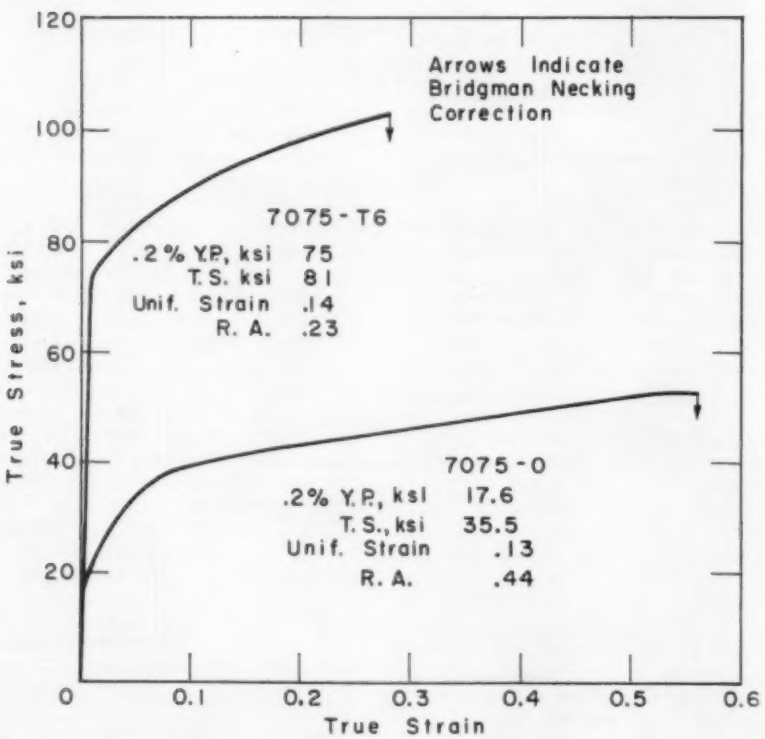

Fig. 4—Tensile properties of 7075 aluminum zinc alloy

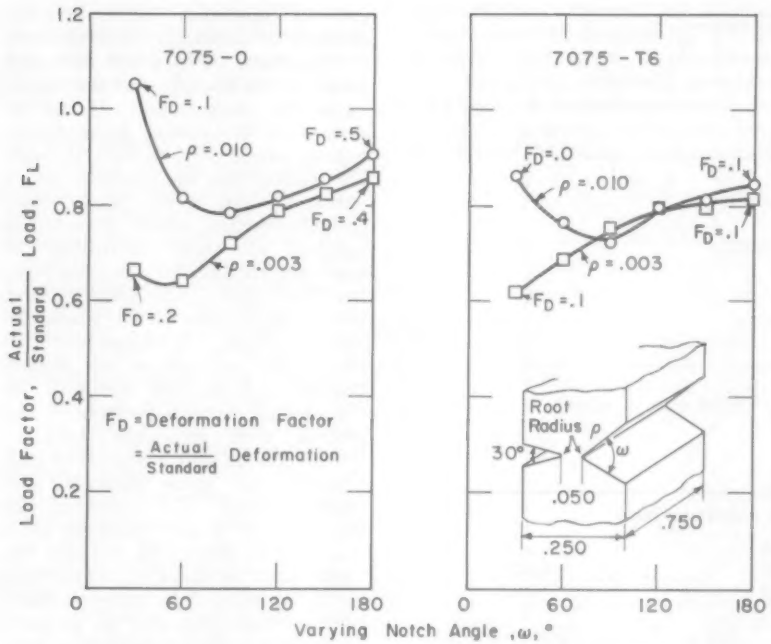

Fig. 5—Load and deformation factors for grooved 7075 aluminum zinc alloy specimens

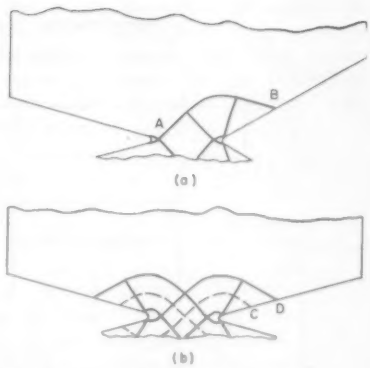

Fig. 6—Plastic flow fields for unsymmetrical and symmetrical grooves

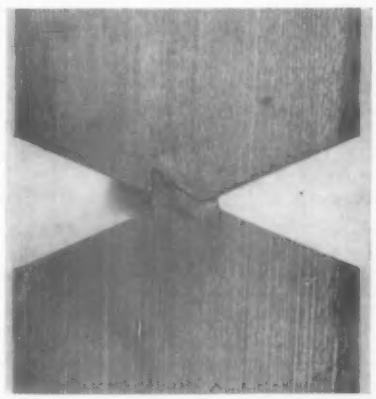

Fig. 7—Fracture of 1 in. thick, doubly-grooved, 7075T6 plate by delamination

the required ratio found according to Appendix A was 5.8 or less, and 0.08% or greater whenever the required ratio was 7.0 or greater, which occurred in the specimens in the O condition with 30- and 60-deg groove angles.

In order to ensure that there was no variability introduced by taking specimens from different bars, by the order of machining, or by the order of testing specimens, a test program was planned with these variables arranged in a Latin square array. All specimens were in the T6 condition with 30-deg notches and a root radius of 0.010 in. The standard deviation of load at fracture was about 4%. Analysis of variance failed to show any effect of order of machining, order of testing, or the particular bar from which the specimens were obtained.

The results are presented in Fig. 5. Deformation factors are tabulated only for the symmetrically- and singly-grooved specimens because of the absence of standard solutions for intermediate cases. Several of the trends were as expected. The load factors are slightly lower for the material in the harder condition. For the singly-grooved hard specimens, the deformation factor is considerably less than for the soft material. For smaller groove angles, the load factors are smaller for the small root radius, i.e., the sharper notch.

An unexpected result was that, while at first the load factor decreases with increasing triaxiality or decreasing groove angle, later the load factor *rises* with increasing triaxiality as the groove angles become equal. This effect is observed in both the hard and soft conditions and, in the case of the soft material, possibly even for the groove radius of 0.003 in. This increase in load factor cannot be ascribed to deformation of the shoulder, because the shoulder deformation was about equal for both the 0.003 and 0.010 root radii and only occurred in the soft condition, whereas the rise in load factor with increasing triaxiality is observed primarily with the larger groove radius and in both the hard and soft conditions.

Since the rise in load factor as the notch angles become equal cannot be ascribed to the triaxiality, differences in strain distribution should be considered. In at least one case the fully-plastic load was reached. Hence a consideration of the fully-plastic displacement fields as sketched in Fig. 6 may be helpful. With unsymmetrical grooves, the flow field is limited to that shown in Fig. 6a, and there are discontinuities in the displacements across the plastic-rigid boundary, AB. But with the symmetrical grooves of Fig. 6b, as Neimark[13] has noted, the flow fields need not contain discontinuities of displacements because the displacements along CD can be chosen arbitrarily. The strain concentrations may be correspondingly lower, deferring fracture. Further work is required to substantiate this hypothesis. However, the fact remains that the unsymmetrically grooved specimens showed lower load factors than those symmetrically grooved. Unsymmetrical notches should be included in studies of the notch sensitivity of material.

Size Effect on 7075-T6 Aluminum Alloy

In large doubly-grooved specimens, fracture occurred by delamination of a longitudinal plane as shown in Fig. 7. Longitudinal cracking under the triaxiality present at the root converted the specimen to an unnotched one of the same thickness which then immediately failed in shear. Reexamination of smaller specimens showed that they too had failed in this complex manner in the presence of a double groove, so further studies were carried out on singly-grooved specimens shown in Fig. 8. It is impossible to avoid bending when pulling a singly-

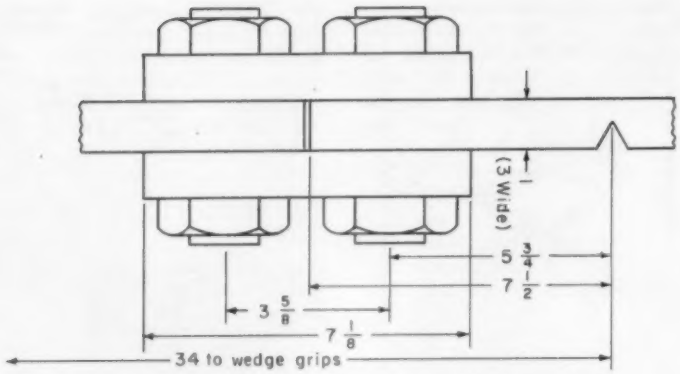

Fig. 8—Mounting for size effect studies. (Small size 1/10 scale)

Table 1—Size Effect in Singly-grooved 7075-T6 Aluminum Alloy

Batch	A		B		
Tensile strength, psi	86,000		83,000		
Reduction of area, fractional	0.16		0.16		
Dimensions, $a_n \times t$, in. ($a_s/a_n = 2$)	0.05 × 0.3	0.5 × 3	0.05 × 0.3	0.5 × 3	
Number of specimens	2	2	4	1	1
Root radius	0.0006, 0.0007	0.011[a]	0.0006–0.0007	0.011[a]	0.010
$F_{CL} = \frac{\text{cracking load}}{\text{standard load}}$	0.52, 0.50	0.32, 0.31	0.46–0.52	0.35	0.39
$F_L = \frac{\text{maximum load}}{\text{standard load}}$	0.59, 0.60	0.36, 0.36	0.64–0.66	0.46	0.44
$F_D = \frac{\text{final deformation}}{\text{standard deformation}}$	0.02, 0.02	0.0004, 0.001	0.02–0.04	0.005	0.002

[a] Imperfect notch with much smaller radius where the arc at the root joined either flank.

Table 2—Doubly-grooved 1100-0 Aluminum Specimens

Stock	1 in. plate		3/4-in. diam bar	
0.2% yield strength, psi	5200		3600	
Tensile strength, psi	12,500		14,000	
Reduction of area, fractional	0.83		0.80	
Root cross section, in.	0.254 x 3.00		0.060 x 0.75	
Root radius, ρ, in.	0.001		0.001	
Shoulder to ligament ratio, a_s/a_n	4		8	
Groove angle, ω, deg	60	30	60	90
No. of specimens	2	4	2	2
Required a_s/a_n, from Appendix A	8–9	15	13	9
Observed thinning of shoulder, $\delta a_s/a_n$	0.016–0.020	0.0005–9	0.0004–5	0.0001
F_L	0.62–0.69	0.56–0.58	0.64–0.65	0.64–0.67
F_D	0.94–1.03	0.87–1.15	1.02–1.15	0.95–1.18

Table 3—Singly-grooved 1100-0 and 99.997% Aluminum Specimens

Composition	1100-0			99.997% pure as received
Stock	1-in. plate			1.12-in. diam bar
0.2% Yield strength, psi	5200			5400
Tensile strength, psi	12,500			8800
Reduction of area, fractional	0.83			0.94
Root cross section, in. ($a_s/a_n = 2$, $\omega = 60$ deg)	0.50 × 2.25		0.050 × 0.225	0.050 × 0.225
Root radius, ρ, in.	0.010	0.001	0.001	0.001
No. of specimens	3	2	2	2
F_L	0.94–0.96	0.90–0.94	1.00–1.01	1.14–1.16
F_D	0.69–0.78	0.67–0.69	0.75–0.85	0.84–0.98

grooved specimen since, in the absence of bending, the resultant of the stress distribution does not lie along the same line in the elastic as in the plastic case. If the resultant of the elastic stress distribution were forced to pass through the center of the section as it naturally does in the plastic case, enough bending would have to be applied so that, according to approximate calculations from Neuber[14] and photoelastic observations, the stress in the notch would be zero or slightly compressive. To allow the specimens to deflect laterally to let the resultant go through its natural position in the section with minimum bending, the specimens were strapped to long bars of the same material and cross section. The criterion for the over-all length between grips was that it should be 4 times the "half life" of bending deflections in the bar when it is under a tension half of that required to produce yielding in a smooth specimen having the same minimum thickness; here this was 68 and 6.8 in. for the large and small specimens respectively.

The tests were carried out on two different, but similar, batches of material as reported in Table 1. Both were stress relieved by 2% extension prior to machining. Although there was some variation in the load at which cracking was first observed, there was very little scatter in the final loads. The increased notch sensitivity over the results shown in Fig. 5 is probably due to sharper root radii and the presence of bending. An imperfect groove root, having the desired radius in the center but smaller radii at the junction with the groove flank, seemed to cause cracking earlier but final failure later, perhaps due to the difficulty of joining the pairs of cracks which were observed to start from both flanks.

The cracks were initially stable, growing only under increase of load. However, they became unstable before the plastic deformation became more than a small fraction of the elastic deformation as judged from the curvature of the load-deformation diagrams. Furthermore, a definite size effect was observed even though the smaller specimens had relatively sharper notches. Both the initial stability followed by instability of the cracks and the size effect might be expected in the light of the theoretical analysis for shear by McClintock,[15] but only the size effect would be predicted from the analyses based

on elastic stress distributions with an assumed constant plastic work per unit crack area, as suggested for example by Orowan[16] and Irwin.[17]

1100-0 Aluminum

In order to see how well the standard load and deformation represent the behavior of a ductile material, tests were run on 1100-0 aluminum, as summarized in Table 2 for doubly-grooved specimens and in Table 3 for singly-grooved specimens. Stress-strain curves are shown in Fig. 9. Of the doubly-grooved specimens, only those with minimum ligament thickness and 90-deg groove angle exhibited negligible shoulder contraction. Nonetheless, similar factors were obtained in all cases, the deformation factor being nearly unity while the load factor was only about two-thirds. In the singly-grooved specimens the situtation was reversed, the load factors being nearly unity while the deformation factors were 0.7 to 0.8. As expected with specimens which fail almost completely by plastic flow rather than cracking, these exhibited less size effect than the 7075 T6 specimens. In an attempt to achieve the full standard deformation, tests were run on aluminum of 99.997% purity. In this case the deformation factor attained unity, but the load factor exceeded it. Deviations from unity may well be due to the large amount of strain hardening present as shown in Fig. 9.

4140 Steel Tubing

The load and deformation factors for circumferentially grooved 4140 steel tubing reported by Schroeder[18] are presented in Fig. 10. The circumferentially-grooved tube corresponds closely to the singly-grooved plate. The tensile strength was taken to be that of ungrooved tubes turned down to the same minimum diameter over a 2 in. length. The grooves were turned with a carbide tool after heat treating, and apparently groove sharpness had relatively little effect within the observed range, except for the load factor in the harder material.

Now to return to the problem of the broken main spar discussed in the Introduction. Plastic deformation will occur throughout a circumferentially-grooved tube of minimum thickness a_n and shoulder thickness a_s when

$$\frac{2T}{\sqrt{3}} a_n F_t > a_s Y \text{ or}$$

$$F_t T/Y > \frac{\sqrt{3}}{2} \frac{a_s}{a_n} \quad (3)$$

A somewhat different, but similar, criterion would be used for a tube grooved only part way around. The important material parameter causing such a structure of ductile material to appear brittle can now be stated. It is not just the load factor or the ratio of tensile to yield strength, but their product $(F_T T/Y)$, where the load factor must be chosen to be consistent with the expected defect, e.g., singly or doubly grooved.

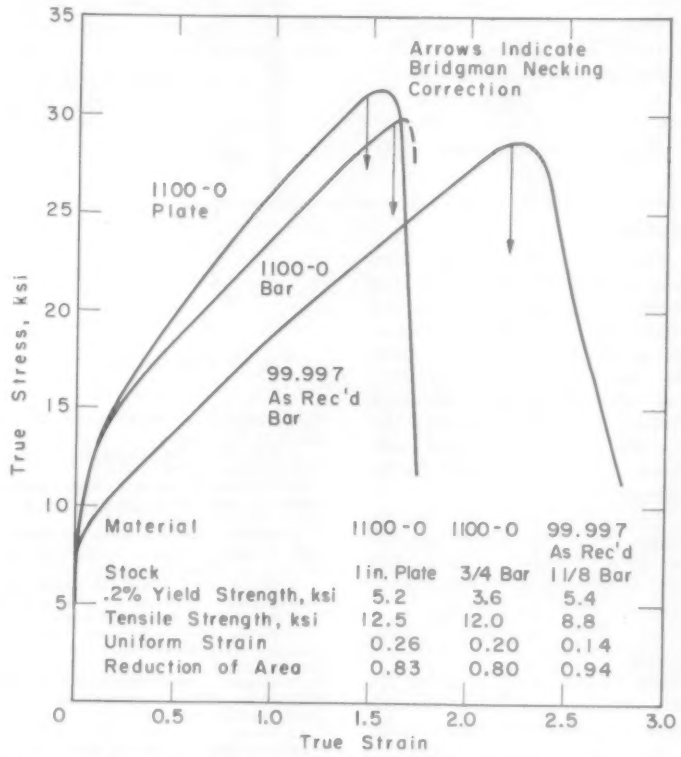

Fig. 9—Tensile properties of commercial and high purity aluminum

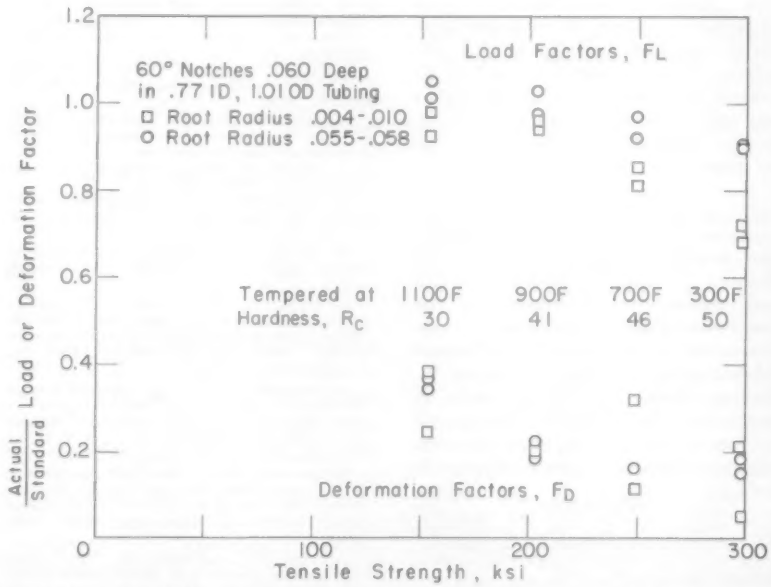

Fig. 10—Load and deformation factors for circumferentially notched 4140 steel tubing

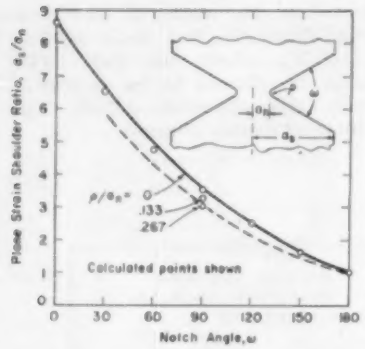

Fig. 11—Required shoulder ratios

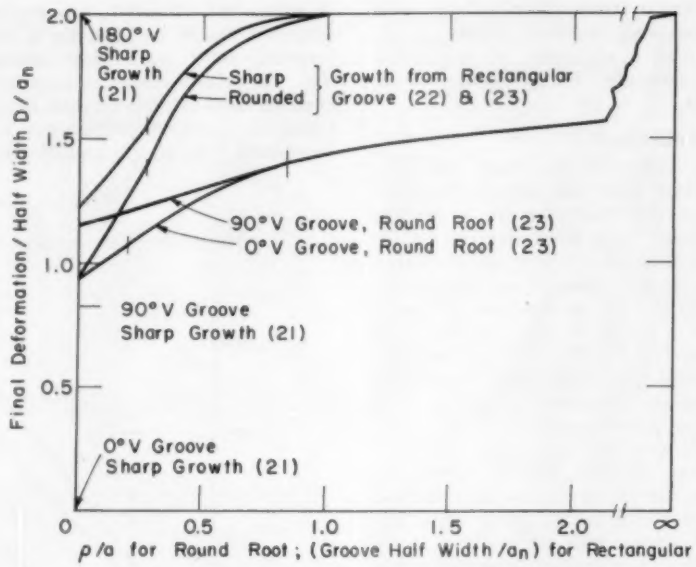
Final Deformation / Half Width D / a_n
180° V Sharp Growth (21)
Sharp
Rounded
Growth from Rectangular Groove (22) & (23)
90° V Groove, Round Root (23)
0° V Groove, Round Root (23)
90° V Groove Sharp Growth (21)
0° V Groove Sharp Growth (21)
ρ/a for Round Root ; (Groove Half Width /a_n) for Rectangular

Fig. 12—Final deformation for doubly-grooved plane-strain specimens

Conclusion

1. The theory of a plastic, nonstrain-hardening material does give reasonably good predictions of the maximum load and final deformation of grooved specimens of fully ductile materials. For doubly-grooved specimens, the shoulder dimensions required to localize the flow in the groove are found both by theory and experiment to be surprisingly large.

2. Triaxiality due to plastic constraint may or may not be present in fully plastic flow around a notch, depending on the configuration and the mode of loading.

3. In singly-grooved tensile specimens which do not develop the fully-plastic load, cracks are initially stable and later become unstable as predicted theoretically and observed experimentally in shear and torsion. Likewise, the load factor of the grooved specimen is found to be size dependent.

4. Load and deformation factors have been defined to help the materials engineer specify to the designer those properties needed to design structures for deformation as well as load-carrying capacity in the presence of possible notches or grooves.

Acknowledgments

In addition to those referred to, the writer wishes to express his thanks to Robert Leonard, without whose careful machining the tests would have not been successful, and to students H. Robert Mousley, J. E. Halle, Freeman W. Fraim, John H. Olsen and, in particular, Alexander C. Mackenzie whose careful testing and observation contributed much to the work.

References

1. Drucker, D. C., "On Obtaining Plane Strain or Plane Stress Conditions in Plasticity," *Proc. 2nd U. S. National Congress Appl. Mech.*, 485–488 (1954).

2. Bishop, J. F. W., "On the Complete Solution to Problems of Deformation of a Plastic-Rigid Material," *Jnl. Mech. Phys. Solids*, **2**, 43–53 1953).

3. Hill, R., *The Mathematical Theory of Plasticity*, Oxford, 250 (1950).

4. McClintock, F. A., "The Plasticity of Singly-Grooved, Plane Strain, Tensile Specimens," in preparation.

5. Hill, R., "On Discontinuous Stress States with Special Reference to Necking in Thin Sheets," *Jnl. Mech. Phys. Solids*, **1**, 19–30 (1952).

6. Shield, R. T., "On the Plastic Flow of Metals under Conditions of Axial Symmetry," *Proc. Roy. Soc., A*, **233**, 267–286 (1955).

7. Levin, E., "Indentation Pressure of a Smooth Circular Punch," *Quart. Appl. Math.*, **13**, 133–137 (1955).

8. Green, A. P., "The Plastic Yielding of Notched Bars Due to Bending," *Quart. Jnl. Mech. Appl. Math.*, **6**, 223–239 (1953).

9. Green, A. P., and Hundy, B. B., "Initial Plastic Yielding in Notch Bend Tests," *Jnl. Mech. Phys. Solids*, **4**, 128–144 (1956).

10. Ford, H., and Lianis, G., "Plastic Yielding of Notched Strips under Conditions of Plane Stress," *Z. Angew. Mathematik u. Physik*, **8**, 360–382 (1957).

11. Walsh, J. B., and Mackenzie, A. C., "Elastic-Plastic Torsion of a Circumferentially Notched Bar," *Jnl. Mech. Phys. Solids*, **7**, 247–257(1959).

12. Hill, R., "A General Theory of Uniqueness and Stability in Elastic-Plastic Solids," *Ibid.*, **6**, 236–249 (1958).

13. Neimark, J. E., "The Initiation of Ductile Fracture in Tension," ScD Thesis, Mechanical Engineering Dept., MIT (1959).

14. Neuber, H., *Kerbspannungslehre*, 2nd edition, Springer, Berlin (1958).

15. McClintock, F. A., "Ductile Fracture Instability in Shear," *Jnl., Appl. Mechanics*, **25**, 582–588 (1958).

16. Orowan, E., "Fracture and Strength of Solids," *Repts. Progr. in Phys.*, **12**, 185–232 (1949).

17. Irwin, G. R., "Fracture Dynamics," *Fracturing of Metals*, 152, ASM (1948). See also "Fracture Mode Transition for a Crack Traversing a Plate," *Jnl., Basic Engineering, ASME*, **82**, 417–425(1960).

18. Schroeder, C. A., "The Effect of Varying Hardness Levels Upon the Tensile Properties of 4140 Tubing Containing Circumferential Notches of Both Low and High Triaxiality," B. S. Thesis, Mechanical Engineering Dept., MIT (1957).

19. Rosenfeld, R. L., "The Initial Deformation of a Rigid-Plastic Work-Hardening Notched Tensile Specimen in Plane Strain," unpublished paper, Mechanical Engineering Dept., MIT (1959).

20. Onat, E. T., and Prager, W., "The Necking of a Tension Specimen in Plane Plastic Flow," *Jnl. Appl. Phys.*, **25**, 491–493 (1954).

21. Lee, E. H., "Plastic Flow in a V-Notched Bar Pulled in Tension," *Jnl. Appl. Mechanics*, **19**, 331–336 (1952).

22. Lee, E. H., "Plastic Flow in a Notched Bar," *Jnl. Appl. Mechanics*, **21**, 140–146 (1954).

23. Lee, E. H., and Wang, A. J., "Plastic Flow in Deeply Notched Bars with Sharp Internal Angles," *Proc. Second U. S. National Congress Appl. Mech.*, 489–497 (1954).

Appendix A—Required Width of Shoulders in Tension

For the commonly published flow fields around notches to be valid, it is necessary that the shoulders be thick enough to prevent plastic flow except around the notch itself. Neimark[13] has extended the calculations of Bishop[2] for zero notch angle and root radius to various values of both these quantities, finding the results shown in Fig. 11.

These theoretical shoulder width ratios were obtained for plane strain of nonstrain-hardening materials and must, therefore, be modified by three factors. The first factor is the ratio of yield in plane strain to yield in uniaxial tension (to which the shoulders are subjected), $2/\sqrt{3}$. The second factor is to guarantee that the maximum load is attained in the notch before yielding occurs in the shoulder. If the relation between strain hardening and reduction of area in the neck of the notched specimen is roughly similar to that in the tensile test, then the appropriate factor is the ratio of yield to tensile strength. Thirdly, if fracture is attained in the notch before the fully-plastic load is reached, then not as large a shoulder is required, and the theoretical ratio should be multiplied by the load factor, F_L.

Combining these three corrections with the ideal shoulder width ratio

gives the shoulder width ratios shown in Fig. 3. The experiments reported in Fig. 5 and Table 2 showed a shoulder thinning of 0.04% or less where the required ratio was not exceeded by more than 15%. On the other hand, they did show greater thinning whenever the required shoulder exceeded the actual one by 40% or more.

Appendix B—Final Deformation of Notched Specimens in Tension

Pending application by Neimark[18] and Rosenfeld[19] of the uniqueness theorems of Hill[12], only rough estimates of the final deformation can be obtained. First, for an ungrooved plate under plane strain, the deformation field suggested by Onat and Prager[20] consists of alternating slip on two 45-deg planes passing through the axis of the neck. This leads to a final deformation at separation equal to the minimum thickness of the specimen. A similar result was obtained by McClintock[4] for singly-grooved plates. For doubly-grooved plates, the results of Lee[21, 22] as well as Lee and Wang[23] are plotted in Fig. 12.

Two different postulates for the deformation around sharp corners resulted in those corners either becoming rounded or remaining sharp. Of these, the rounded-growth assumption seems preferable, not only judging from the initial deformation vectors, but also because it gives results consistent with the limiting case of a rounded groove with vanishingly small root radius. From Fig. 12, a final deformation of a_n was chosen for notch angles less than 90 deg and root radii less than 0.2 a_n.

EUROPEAN WELDING RESEARCH

By Gerard E. Claussen

ITALY

Photographs of submerged-arc installations for diesel locomotives in Italy are shown in *Rivista di Meccanica*, July 18, 1960.

RUMANIA

The journal *Stiinte Tehnice* of the Scientific Research Society of Rumania for the second half of 1959 contains three papers on welding. A paper on the flash welding of rails describes induction coils for controlling the rate of preheat. The second paper summarizes the effect on arc stability of 15 components of electrode coatings. The length and voltage of the arc at extinction on direct current, both polarities, and on alternating current were the criteria. Mica and psilomelane were rated high as stabilizers. The third paper provides nomograms for determining heating and cooling rates in the vicinity of arc welds. Rykalin's formulas for temperature distribution were the basis for the work.

SWITZERLAND

The Swiss magazine *Zeitschrift für Schweisstechnik* for July and August 1960 contains an article on the theory of metal spraying with a gas flame and compressed air. The smaller the spray angle, the higher is the efficiency of metal deposition Compared with other metals, the efficiency for zinc spraying is very low, being 60–85%. The sprayed particles are 50 to 200μ in diam, are about 15° F above the melting point of the wire, travel at a speed of 350 mph, and require 60 to 200-msec to travel from torch to work. The droplets are in a liquid-plastic condition as they spread into a disk shape upon striking the work.

USSR

The July 1960 issue of *Avtomaticheskaya Svarka* contains the following articles:

• By means of block diagrams and in general terms, the application of feedback and cybernetic principles to the simplification and perfection of arc welding control system is explained.

• Large diameter, thick-walled steam pipes of steel containing 14 Cr, 14 Ni, 2.5 W, 0.5 Mo for operation at 1100° F developed cracks in the heat-affected zone of butt welds made with austenitic electrodes. The cracking was related to precipitation of grain boundary carbides during welding and to residual stresses. Heat treatment for 1 hr at 1920° F was beneficial.

• The press forming of "I" beams and box sections from sheet steel is shown to be useful in welded design.

• To secure weld deposits containing 19–21% Mn, 5% Al, the problems of hot cracking and of reduction of silicon and carbon from the lime-base coating were solved. Increase in carbon and silicon lowered the ductility. A small amount of ferrite decreased the tendency to hot cracking. The amount of reduced silicon and carbon was directly proportional to the sodium silicate and $CaCO_3$ contents of the coating.

• Increasing the cooling rate of argon-shielded welds in Type 316 and Type 321 stainless steels made with stainless steel electrode by a water spray trailing the arc, did not decrease the rate of general corrosion, but decreased the tendency to knife line attack, without eliminating it.

• Cast iron strips were deposited at 750 amp on mild-steel plates by submerged-arc welding under pumice-type flux. As the cooling rate was decreased by preheat and decrease in plate thickness, the amount of cracking and primary cementite also decreased. When the cooling rate of multiple-pass deposits was lowered below 36° F per sec at 2100° F, cracking was avoided and the hardness was 42 Rockwell C maximum.

• A control was evolved for flash welding that provided the maximum frequency of flashing prior to upset for mild steel.

• In electroslag welding of steel with strip electrodes, fluctuations of current increase in magnitude as the width increases. The fluctuations are due to the melting of the strip as the arc travels from one edge to the other. Beyond a width of 5 in., the fluctuations become so violent that the penetration pattern becomes irregular.

• The use of portable electroslag

(*Continued on page 228-s*)

DR. GERARD E. CLAUSSEN is associated with Arcrods Corp., Sparrows Point, Md.

Notes on the Assessment of Filler Metals and Fluxes

Paper sponsored by IIW attaches significance to wetting power as distinguished from surface tension and viscosity as result of investigation on brazing fluxes and filler metals

BY G. M. A. BLANC, J. COLBUS AND C. G. KEEL

Introduction

Industrial brazing procedures have become indispensable methods of production. New metals, alloys and solders are always being proposed. Against this background, the International Institute of Welding has during recent years, successfully started to work out recommendations for filler metals. The problem appears increasingly complicated both technologically and scientifically, and it is not easy to get a clear picture of it.

Today, requirements for technical solders and fluxes are largely set up empirically. For instance, users are satisfied with the enumeration of the chemical composition, the solidus and liquidus temperatures and simple mechanical properties. There is, moreover, not certainty as to the meaning of important physical values such as the surface tension, viscosity, etc., of filler metals and fluxes. By way of contrast, the concept of "wetting power" is largely indeterminate, and little is known of the relationship existing between the individual factors. Recent research has shown that the physical values of surface tension and viscosity of filler metals and fluxes indicate little in brazing technology, and thus have no significance. Accordingly, attempts have been made to give preference to other characteristics, such as "spreading" (wetting), since they can give indications which accord more closely with practice.

The present survey attempts to add something to this work. The first part of this survey deals with the physical meaning of the surface tension of filler metals, and fluxes and gives the results of new experiments. The second part attempts to present the new technical concepts such as "wetting power." The third part indicates several interesting relationships between the characteristic values mentioned above and which are important for both theory and practice.

G. M. A. BLANC is Managing Director, Fontargen A.G., Zurich-Oerlikon, Switzerland; J. COLBUS is Director of Staatl. Institut f. Schweisstechnik, Germany; and C. G. KEEL is Director of the Swiss Welding Association, Switzerland.

IIW paper presented at AWS 42nd Annual Meeting held in New York, N. Y., Apr. 17–21, 1961.

Surface Tension as a Physical Concept

Formation of Surface Tension

The phenomenon of surface tension can be explained by the mutual attraction existing between the different particles of a liquid. While the attraction forces for a particle in the inner of the liquid compensate each other (because the particle is attracted equally from all sides), there results for a particle on the surface (because of the one-sided attraction) a force directed toward the inner of the liquid, upon which the surface tension depends. The surface tension of liquids is measured in dyn/cm or erg/cm^2.

Methods for Determining Surface Tensions

Surface tension can be evaluated experimentally as a function of temperature by the following methods:

1. Method of capillary rise[1]
2. Method of laying drop[2]
3. Method of bubble pressure[3]
4. Method of oscillating jet[4]
5. Method of capillary filling pressure[5]
6. Calculation from the dimensions of the meniscus[6]

All these methods are summed up in Fig. 1, which also indicates the relevant calculation formulas.

Pure Metals

Figure 2 summarizes some of the surface tension values published in the literature for copper, lead, magnesium, zinc, tin and aluminium as a function of temperature. It is remarkable that all the values decrease with increasing temperature barring those of copper. The reason for this is unknown.[3, 7, 8]

All measurements appear to have been carried out with the use of fluxes. More accurate data are lacking.

Surface Tension of Binary Alloys

Pelzel published some valuable results of the systems Al–Mg and Al–Zn which are summed up in Fig. 3. Draht and Sauerwald report on the system Cu–Sn. It would be advantageous if other systems used in modern brazing techniques could also be examined.

Surface Tension of Ternary and Quaternary Systems

Published Dates. Only individual values can be found in the literature concerning alloys of these systems. For this reason, some tests were conducted to gain more information at the Polytechnical School in Zurich as later reported in this paper.

Filler Metals and Fluxes Used. Three filler metals and two fluxes were examined. The filler metals, of the usual commercial type, were analyzed and found to have the compositions shown in Table 1.

Analysis of the fluxes gave the compositions in Table 2. No data are available on the surface tension of these alloys or similar ones.

Test Results. All results are combined in Table 3 and Fig. 4. Tests on filler metals A, B and C only produced normally usable results when using the bubble-pressure method.

Review of Test Results

The published research and the present results show that determination of the surface tension of *pure metals and binary alloys* is not difficult. However, with *ternary and quaternary systems*, which are

Table 1—Commercial-type Filler Metal Compositions

	Compositions, %	Solidus, °C	Liquidus, °C
Filler metal A			
Copper	60.5	834–860	870–885
Zinc	38.8		
Silicon	0.38		
Tin	0.32		
Lead	Traces		
Filler metal B			
Copper	46.2	870–880	888–902
Nickel	11.0		
Silicon	0.4		
Silver	0.4		
Phosphorus	0.05		
Zinc	41.95		
Lead iron manganese	Traces		
Filler metal C			
Silver	40.0	584–588	606–610
Cadmium	28.0		
Copper	17.5		
Zinc	14.5		

Table 2—Flux Compositions

Flux No. 1 (fusion temperature 850° C, $\gamma = 2.05$ g/cm³)		
Borax	$Na_2B_4O_7$	37.1%
Boric acid	H_3BO_3	56.3%
Calcium chloride	$CaCl_2$	2.4%
Sodium chloride	Na Cl	3.0%
Phosphoric anhydride	P_2O_5	0.6%
Flux No. 2 (fusion temperature 650° C, $\gamma = 2.1$ g/cm³)		
Potassium fluorborate	KBF_4	60.0%
Potassium tetraborate	$K_2B_4O_7$	30.2%
Water	H_2O	9.0%

customary in filler metals, this involves very considerable difficulties.

The tests carried out on the measurement of surface tension gave no uniform values. Only the bubble-pressure method and the laying drop method gave acceptable and comparable results. The other methods do not seem to be suited to these alloy filler metals. The check measurements carried out with Hg and Cu were, however, satisfactory. Fluxes 1 and 2 could only be satisfactorily tested with method 3.[9]

Table 3—Survey of the Test Results

Method	Filler metal A	Filler metal B	Filler metal C	Hg[a] Dyn/cm	Cu[a] (T = 1140 °C) Dyn/cm	Flux 1	Flux 2
1. Bubble-pressure	v. Fig. 4	v. Fig. 4	v. Fig. 4	472–478	1140	...	...
2. Capillary depression	Unusable	Unusable	Unusable	472–478	1130	...	...
3. Oscillating jet	Unusable	Unusable	Unusable	472–478	1140	250 at 950° C	120 at 650° C
4. Laying drop	...	...	v. Fig. 4	...	...	...	...

[a] Check tests.

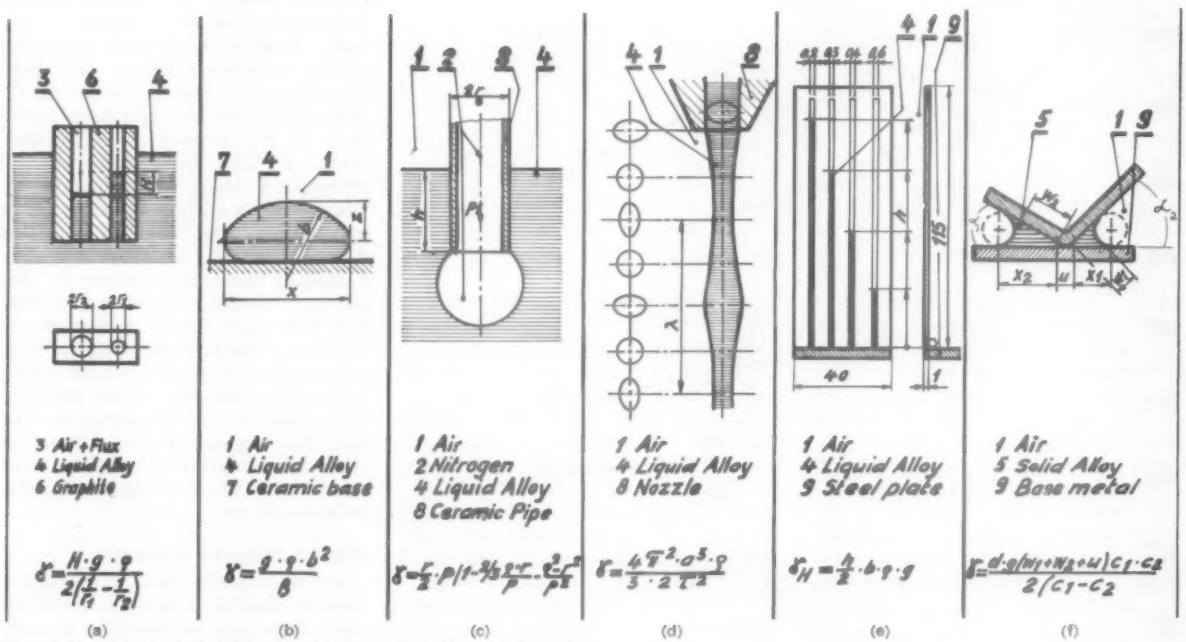

Fig. 1—Summary of methods for determination of surface tension

(a) Method of capillary rise: γ = surface tension, ρ = density, g = gravitation constant, r_1 = radius of the small capillary tube, r_2 = radius of the large capillary tube, H = difference between the domes (meniscuses).

(b) Method of laying drop: γ = surface tension, ρ = density, g = gravitation constant, b = curvature radius, x = largest horizontal section, z = height above the largest horizontal section area, β = parameter = x/z.

(c) Method of bubble pressure: γ = surface tension, ρ = density, r = outer radius of the capillary tube, $P = P_1 - h\rho$.

(d) Method of oscillating jet: ρ = density, a = medium radius of the nozzle aperture, c = efflux speed, $\tau = \lambda/c$ = oscillation time in seconds.

(e) Method of capillary filling pressure: ρ = density, g = gravitation constant, h = elevation, b = gap width.

(f) Calculation from the meniscus: g = gravitation constant, d = density of the filler metal, $c_1 = 2 \cdot x_1 \cdot \sin \alpha 1$, $c_2 = 2 \cdot x_2 \cdot \sin \alpha 2$.

Table 4—Classification of Some "Surface Active Elements" in Filler Metals

Filler metal	"Surface-active Elements"	Weight, %	Base material	Kind of the compound	Reference
Cu	P	P = 0.04–0.08	Steel	...	[a]
Cu	Ag	0.6 max	Steel	...	[a]
59 Cu, 40 Zn	Si, Ni, Mn, Cu	0.1–0.2	Steel	...	[a]
63 Cu, 37 Zn	Si	0.5 max	Steel	...	[a]
71, 5 Ag, 28.5 Cu (Eut.)	Si	0.5 max	Mo, W	($MoSi_2$) solid solutions, (W Si_2) Si-Mo/W	5
Ag	Cu_3P	0.02	Steel	$Cu_3P + Fe = Fe_3P + 3Cu$	5
Ag	Pd	1–5	Steel	...	5
Ag	Ba	1	Steel	...	12
Ag	Li	1	Steel	...	12
75 Pb–20 Sn	Hg	5	Steel	...	13
40 Ni–59 Pd	Si & Be	0.5–1.0	Steel, Ti Al-alloy	...	14
93.5 Pb	Sn & Ag	5 Sn + 1.5 Ag	Steel, Cu	...	15
99.9 Sn	Ni	0.1	Cu	...	15

[a] Analysis of commercial filler metals.

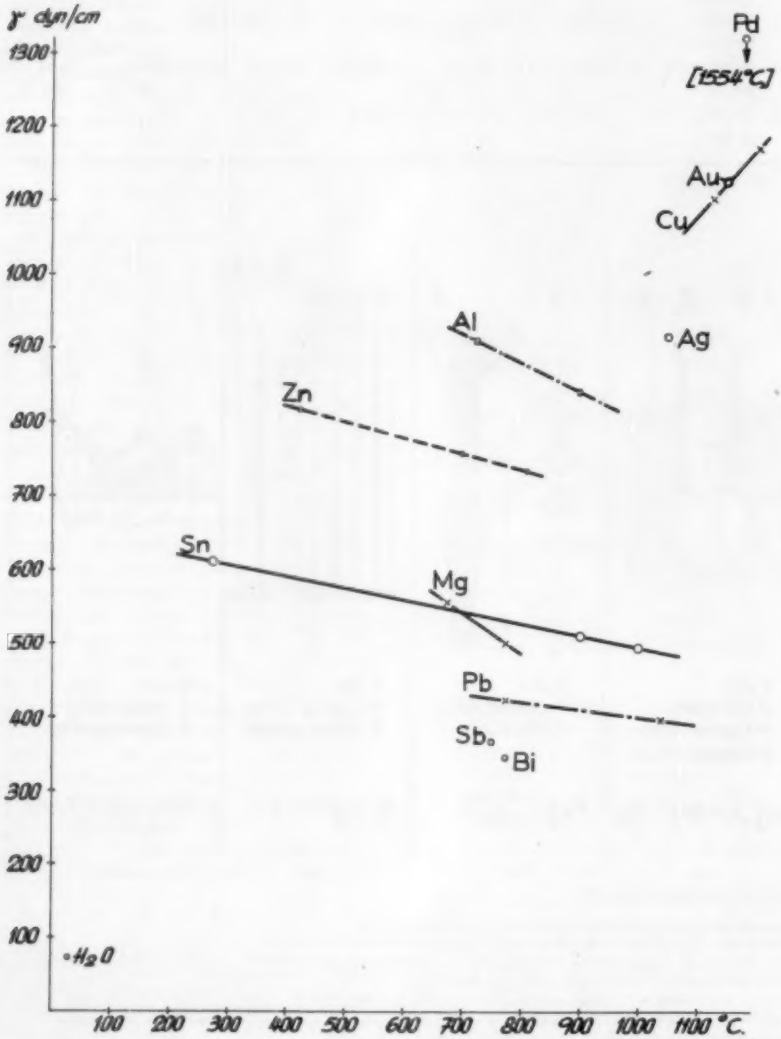

Fig. 2—Surface tension = f (T)[3, 7, 8]

In view of the extensive scattering of the test results, there is only one limited possibility of comparing the results between the individual methods. The cause of this wide scattering may be that melts with different types of atoms clearly have interior tension or interior viscosities which differ from those on the outside. Furthermore, with Zn containing filler metals, exact measurement is also made difficult since these metals melt at temperatures where the zinc is already evaporating or its steam pressure has already reached a considerable value.

It clearly seems impossible to get uniform values of nonferrous alloys with extremely different types of atoms. Dynamic methods are least suited, because capillary active substances tend to move to the surface; in the case of the oscillating jet, for instance, they falsify the regular formation of nodes and internodes because of their measuring inertness. Probably supplementary forces are constantly attempting to transform the shape of the surface. Oxidation during efflux, caused by the extremely different melting and evaporation points, also complicates the readings extensively.

In measurement by the bubble pressure method, the surface tension is measured in the *interior of the melt*. It seems that there are more stable conditions there, and this is confirmed by the results obtained. Although measurements have been made in the interior of the melted mass, it has been indisputably established that the addition of fluxes reduces surface tension. This may come from the fact that the stirring caused by the medium frequency induction promotes the mixture of the melt with the flux. On the other hand, valuable indications have been found about temperature dependence of the surface tension of alloys which still are little known. With regard to the negative result of this "critical review of methods," further accurate scientific investigation would be welcome.

Effect of Dissolved Substances

It is known that the surface tension of a liquid in air is varied by the substances dissolved in it and, in fact, can be both increased and decreased (Gibbs-Law). This law is valid for liquid brazing alloys in air only. For the system liquid brazing alloy-base metal at higher temperatures, this law may not be valid, because there thermodynamic equilibrium is lacking.[10] There is

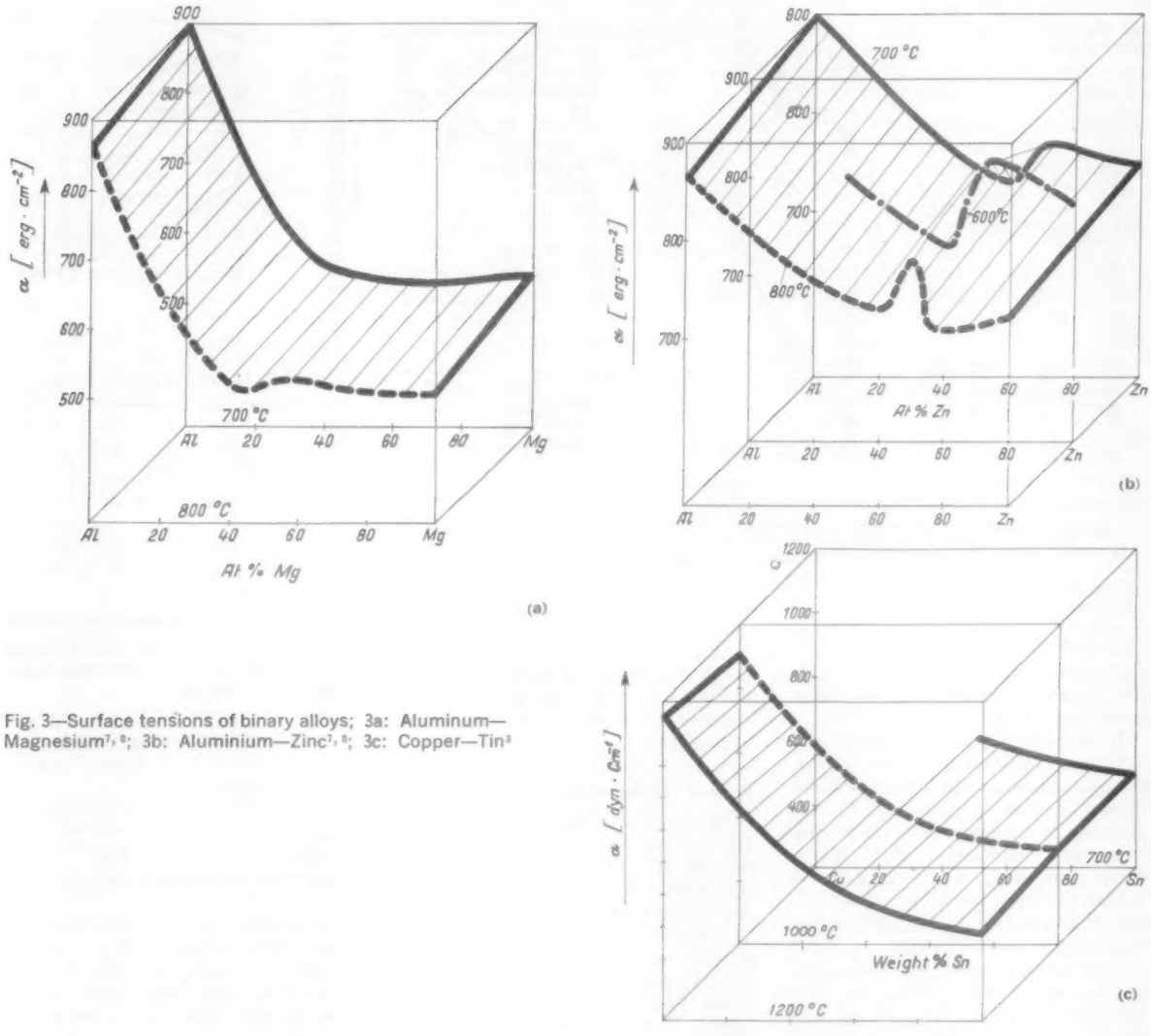

Fig. 3—Surface tensions of binary alloys; 3a: Aluminum—Magnesium[7, 8]; 3b: Aluminium—Zinc[7, 8]; 3c: Copper—Tin[3]

extremely little known about the quantitative extent of the effect of dissolved substances on melted metal, except cast iron.

Research of the last years has nevertheless shown that the properties of known filler metals can be improved considerably by the addition of small amounts of "surface active" substances. Some examples of these have been compiled in Table 4. These elements, although present in a small concentration, can have a major influence on the brazing alloys. In view of more recent theories their function lies in their ability to form solutions with negative formation enthalpy with certain elements of the base metal. By this a certain amount of heat, i.e., energy, is liberated and facilitates the wetting of the brazing alloy on the base metal.

Effect of Silicon on Wetting and Tensile Strength of Brass Filler Metals

A well-known supplementary element is silicon, which is added to the brass filler metals used in the trade up to 0.5%. Its effect was thoroughly investigated. In this connection, interest is directed exclusively toward the interaction between tensile strength and wetting (spreading area).

In Fig. 5, Curve A indicates the tensile strength of deposited filler metal with 0.10, 0.17 and 0.25% Si. The test was performed according to the IIW recommendations in Doc. I-35-56. As the Si content is augmented, the tensile strength of the fused filler metal increases by 1 kg/mm². The wetting power of filler metals with an increased silicon content of 0.1 to 0.3% decreases to between 295 and 270 mm², as shown in curve C. The decrease is almost rectilinear. The strength of gap-brazed joints on steel with a tensile strength of 50 kg/mm² drops from an average of 39 kg/mm² with 0.1% Si to an average of 30 kg/mm² with 0.3% Si (Curve B). The cross section of the brazed joint was 30 x 8 mm². These tests also indicate that certain inter-relationships exist between "wetting power" and tensile strength, so that with greater wetting power a higher tensile strength may be anticipated. Furthermore, these tests also show that the actual filler metal tensile strength—that of the deposited filler metal—is no guide to tensile strength. The wetting power is a better criterion, since the tensile strength of the brazed joint can be

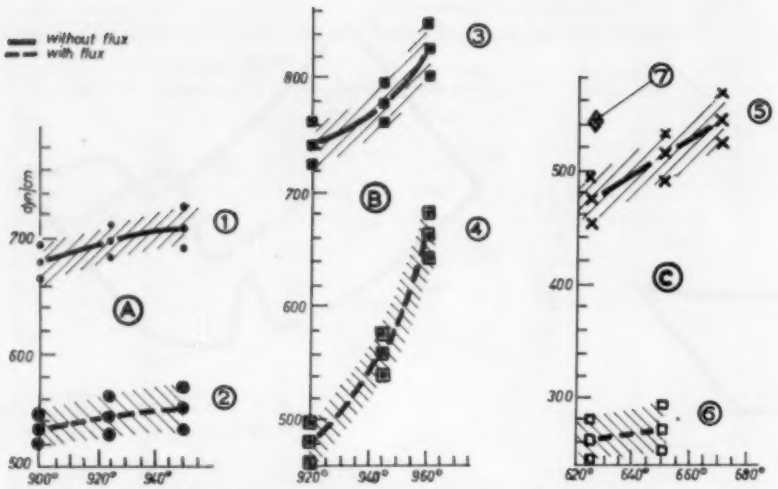

Fig. 4—Surface tension of filler metals A, B and C as determined by the "bubble-pressure-method" and the "laying drop-method"

A, B and C: Filler metals A, B, C respectively—(1, 3, 5) surface tension of the alloy in argon without flux; (2, 4) same, under flux No. 1; (6) same, under flux No. 2; (7) same, in air, without flux.

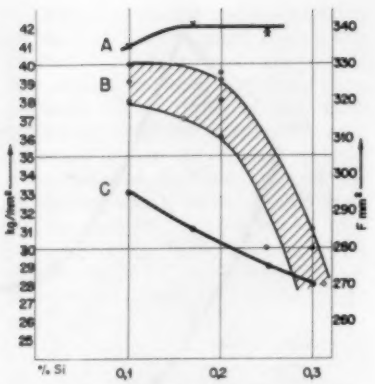

Fig. 5—Brazing alloys 60% Cu – 40% Zn with different silicon-contents. A, Mechanical resistance of the alloy; B, Mechanical resistance of the joint; C, Surface of the wetted area

appreciably reduced even though the tensile strength of the filler metal is increased.

In the literature, it is sometimes indicated[16] that with a rise in the silicon content the "fluidity" of brass likewise increases, i.e., its viscosity is reduced. The assertions were not checked. But it is clear that if in fact viscosity is reduced, the "wetting power"—and thus the tensile strength of the brazed joint—deteriorates.

The present tests and those on which we report later on (v. Interrelationships, Figs. 12, 13, 14) show (a) that a given filler metal with a given temperature, i.e., with the same respective viscosity and surface tension, has different wetting powers and thus different tensile strengths according to the viscosity of the flux, and (*b*) that if small quantities of alloy elements are added to the filler metal, these reduce the wetting power and the tensile strength of the joint, even if the tensile strength of the filler metal and the fluidity are improved by these additions. Here too it may be concluded that, in brazing, the "viscosity" and "surface tension" of filler metals do not appear to be unequivocal characteristic values in every case, and that other processes act on the wetting power and the tensile strength of the joint as "boundary layer reactions" between filler metal and base metal. Furthermore the viscosity of a given flux can be influenced by reactions with the base metal. If such reactions take place, i.e. metal or metal oxide molecules diffuse into the flux, the relationships outlined above can be altered or nullified.

Surface Tension of Fluxes

In brazing practice knowledge of the surface tension of fluxes is also important. Unfortunately it is impossible to find numerical data about this in the literature.

Results of Measurements. The surface tension of a flux 2.2 g/cm³ specific gravity at higher temperatures has been investigated by Miller.[17] He indicates 185 Dyn/cm at 582° C. Our tests with flux no. 1, using the oscillating jet method, gave approx. 250 Dyn/cm at 950° C; flux No. 2 gave approx. 120 Dyn/cm. (T = 650° C).

It is known that organic wetting agents reducing surface tension are added to fluxes soluble in water, thus wetting the base metal satisfactorily at room temperature.

The Effect of Wetting Agents in Fluxes on the Wetting Power (Spread) of Fluxes and Filler Metal

Soft soldering. In practice, surface-active substances are added to liquid fluxes for soft soldering, thus promoting spreading and wetting by the flux—particularly on greasy and oily surfaces—and ensuring the efficient and positive penetration of the flux into corners, edges and gaps. The effect of the wetting agent in fluxes on the wetting power of both fluxes and filler metals will now be examined. The flux used in the tests below was a 1:5 dilution of a concentrated solution of an eutectic mixture of ZnCl and NH_4Cl. 0.2% of wetting agent was added to the concentrate when the action of the wetting agent was to be tested.

Table 5—Surface Tension and Viscosity of a Flux with and Without Wetting Agent Added (T = +20° C)

	Without wetting agent	With wetting agent
Surface tension dyn.-cm^{-1}	56.25	32.25
Viscosity degrees Engler	1.12	1.08

Table 5 indicates at the top the surface tensions of the fluxes used *with* and *without* wetting agents. The values indicated are averages obtained from direct measurements according to the elevation in capillary tubes and indirect measurements according to the drop method (Stalagmometer). Both methods produced values which correspond satisfactorily to each other. It can be determined that the surface tension of the flux is reduced to 57.25% of the original value by the addition of the wetting agent. The changes in viscosity are entered in the lower section of Table 5. These indicate that the viscosity is reduced.

A 0.05 cm³ drop was applied to copper and steel plates at room temperature. These plates had either a bright and smooth surface (polished) or were sandblasted or ground in *one* direction with a normal workshop grinding wheel.

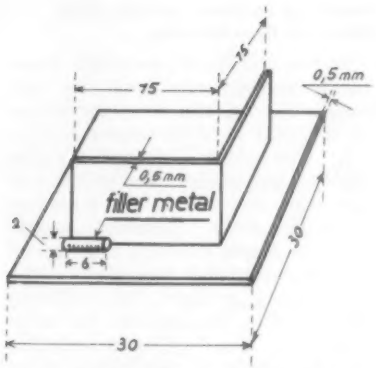

Fig. 6—Test specimen for determination of the spreading time

Table 6—Effect of Wetting Agents on the Spreading of 0.05 cm³ Flux at Room Temperature and Various Surface-qualities of Copper and Steel[a]

Type of treatment of the surface of the base metals	Spreading, mm², on Copper: Without wetting agent	Copper: With wetting agent	Steel: Without wetting agent	Steel: With wetting agent
Polished	50	85	80	130
Sand blasting	70	600	75	840
Ground with emery	55	110	65	130

[a] Aqueous solution 1:5 of a concentrated solution of an eutectic mixture of $ZnCl_2$ and NH_4Cl.

Table 7—Effect of Wetting Agents on the Spreading of 0.12 g of Filler Metal (40% Sn–60% Pb) at 250° C on Copper and Steel with Different Surface Treatments

Type of surface treatment	Spreading of the brazing alloy, mm, on Copper: Without wetting agent	Copper: With wetting agent	Steel: Without wetting agent	Steel: With wetting agent
Polished	70	90	130	130
Sand blasted	215	250	155	350
Ground with emery	330	390	200	415

The surfaces were treated in different ways in order to determine the effect of the surface quality on the spread.

Table 6 shows the changes in the spread of drops of flux with and without wetting agents on the various surfaces treated. The following can be seen:

(*a*) On polished surfaces the spread is increased by about 60 to 70% through the addition of a wetting agent.

(*b*) On sand-blasted surfaces the spread is increased up to 1000% by the addition of a wetting agent.

(*c*) On ground surfaces the spread of the flux is increased by 100% by the wetting agent.

Table 7 shows the effect of the spread of the fluxes on the spread of 0.12 g filler metal comprising 40% Sn and 60% Pb. Here too it may be concluded that a greater spread of flux leads to a greater spread of filler metal. The percentage increase between the spreads "with" and "without" wetting agents is no longer as large as with the spread of the flux at room temperature. However, the effect of surface qualities in the brazing tests is much more noticeable as the effect of the wetting agent. The boundary surfaces—processes which take place during brazing—are the decisive factors. The surfaces of sand-blasted and ground areas are greater than those of smooth areas of the same size. The former, therefore, have greater free energy (unreleased molecular and atomic energy).

The capillary effect of the grooves is also a factor in surfaces ground in *one* direction. These considerations explain the increase of wetting in the order polished—sand-blasted—ground.[18]

These tests also lead to the conclusion that the surface tension and viscosity of the filler metal do not determine wetting, since all the filler metals investigated had identical surface tension and viscosity during the course of the tests. It is rather that the wetting power is affected by processes on the boundary surface between filler metal and base metal in addition to the surface tension and viscosity of the fluxes.

Brazing. Using silver filler metal (45% Ag) and an addition of 0.4% wetting agent in the paste an increase in the spread of 25 to 40% according to the base metal, could be observed—Table 8. In order to estimate the effect of the flux on the time factor, which is important in brazing practice, this time factor was measured as shown in Fig. 6. The testpiece was covered on the edges of the angle with the flux paste to be tested and placed in an oven at a temperature 10% above the working temperature of the filler metal (= 660° C in the present instance). When the drops of filler metal melted, a measurement was made for the time taken for the filler metal to circulate over both sides of the angle. Table 8 indicates the reductions in the time factor resulting from the wetting agent in the flux; these range from 45 to 80% according to the base metal. These values and the values in Tables 6 and 7 are averages taken from a minimum of 10 separate measurements in each case.

The effect of wetting agents on the wetting power of the filler metal can further be explained with soft solder fluxes fluid at room temperature—aqueous solutions were used in the test—by the *increase of the spread of the fluxes* subsequent to the addition of the wetting agent, resulting from the reduction of the surface tension.

Table 8—Effects of Wetting Agents in Fluxes for Silver-brazing on Spreading and Brazing Time

Base metal	Increase of spreading, %	Decrease of the brazing time (Fig. 6), %
Steel	40	45
Copper	25	80
Brass	30	45

Explanation of the effect of wetting agents in flux pastes for brazing is much more difficult. Borates and fluorides, the active ingredients in brazing fluxes, remain in a solid state at room temperature. They do not liquify until just before brazing temperature and only then start to spread. At these temperatures, the organic wetting agents are already burned up or evaporated and can thus have no further effect on the spreading of the flux. The following considerations may provide an explanation for the better spread and smaller time factor definitely observed when using wetting agents: As a result of the surface-active effect of the wetting agents the pastes, particularly the solid active components in fine powder form, are spread much more homogeneously and equally on the brazing surfaces than when there is no wetting agent in the paste. These components, finely distributed and equally spread, melt simultaneously and equally as soon as they reach their liquidus temperature. A uniform and smooth film of molten flux is thus rapidly formed on the

Table 9—Effect of Flux on Filler Metal Surface Tensions, Dyn/cm[15]

Metal	Fluxes			
	Hydrogen	Colophony	Zinc ammonium-chloride	Tin-chloride
Tin	550	442	422	342
Tin-lead-eutectic	490	380	331	..
Lead	440	316	..	..

brazing area. This uniform film dissolves the oxides evenly, thus obviating all disturbances that could restrict the wetting of the filler metal.[19]

Influence of Fluxes on the Surface Tension of a Filler Metal

The effect of fluxes on the surface tension of a filler metal composed of metals and alloys is extremely complex. In certain circumstances fluxes are capable of reducing the surface tension of the filler metal quite considerably—Table 9.[15] Miller[17] found for the aluminum filler metal X-716—with flux No. 33: 680–695 Dyn/cm and with flux No. 51: 250–260 Dyn/cm.

Our tests show clearly that fluxes 1 and 2 are capable of reducing the surface tension of filler metals A–C considerably—Figs. 4a–4c.

Surface Tension and Wetting Power as Technical Concepts in Brazing

The physical considerations described above regarding surface tension are clearly not satisfactory for the brazing specialist. They do not show, for example, suitable correlations with practical results. The phenomena of the "wetting" of a base metal by the liquid filler metal is considerably more meaningful to the specialist.

Interfacial Reactions between Filler Metal and Base Material

In the literature concerning brazing technology one finds the representation of the drop spreading on a metal base as shown in Fig. 7-1. The angle α formed by the edge of the liquid filler metal and the base material is the so-called "wetting angle" (contact angle), which depends on both filler metal and base material and also on the surrounding medium, i.e., either a flux or the atmosphere of some protective gas. Physics explains the spreading of this filler metal drop as the effect of three vectors which are stated in the equation listed in Fig. 7.

Of the three vectors γ_{13}, γ_{12} and γ_{23}, only the last one γ_{23}—that is to say the *surface tension*—is measurable. The other two vectors—namely, the *bonding tension* and the *spreading tension*—cannot be measured directly. Therefore, if one speaks of "surface tension" of filler metal or fluxes, one always understands the *tension* γ_{2-3}.

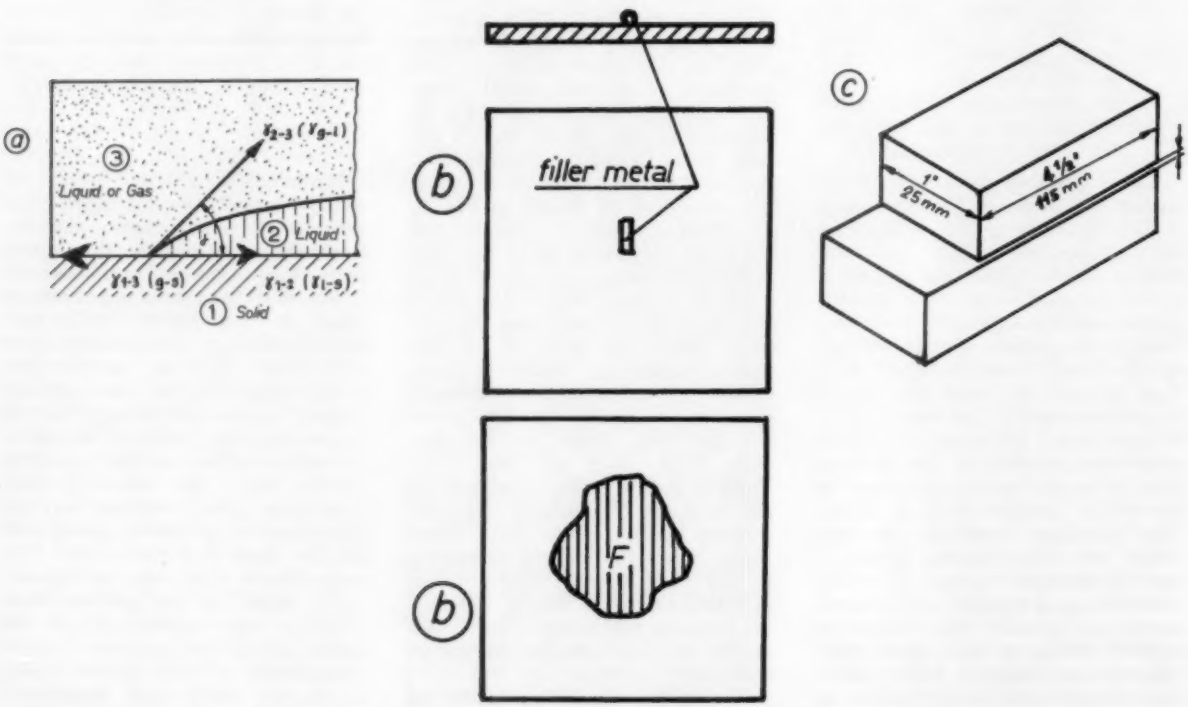

Fig. 7—Spreading tension, surface tension, bonding tension and wetting

(a) Surface tension γ_{2-3}. Spreading tension $\gamma_{1-3} = \gamma_{1-2} + \gamma_{2-3} \cdot \cos \alpha$; bonding tension $\gamma_B = \gamma_{1-3} - \gamma_{1-2} = \gamma_{2-3} \cdot \cos \alpha$; contact angle = α. Results very good with α = 0–10 deg, good with α = 10–30 deg, satisfactory with α = 30–50 deg, bad with α = 50–90 deg and nonwetting with $\alpha > 90$ deg.
(b) Wetted surface determination by planimetric measurements. "Wetting Index" $W = F \cos \alpha$, with F = surface and α = contact angle.[14] Wettability excellent with F = 0.5 sq. in., very good with F = 0.3 sq in., good with F = 0.2 sq in., satisfactory with F = 0.1 sq in., and bad with F < 0.1 sq in.
(c) "Penetration Coefficient" P[18]. Includes wetted surface, total surface and brazing time. Space indicated by facing arrow heads is 0.0035 or 0.006 in.

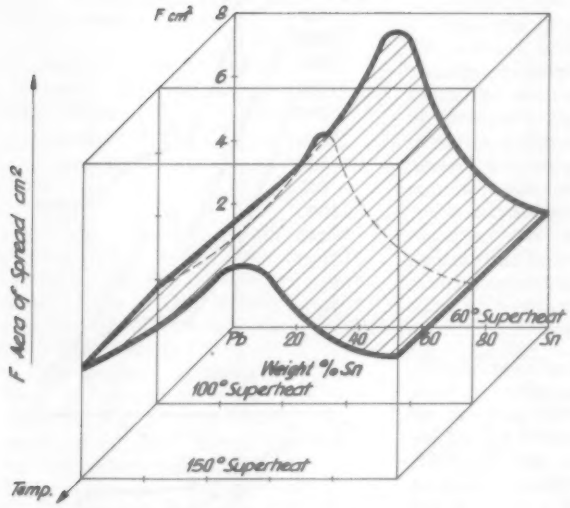

Fig. 8—Brazing alloy: Pb-Sn. Wettability of Cu[15]

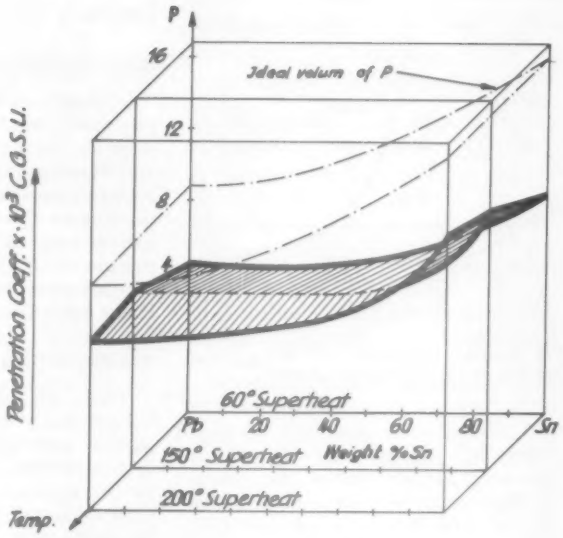

Fig. 9—Penetration of Pb-Sn-alloy in Cu-joints 4 1/2 in. long x 1 in. wide and 0.0035 in. depth[15]

Concept of "Wetting Power"

During recent years, detailed reports have been made on this very important problem in the technical literature. This concept means the extent of the wetting of the base material by a filler metal or a flux.

Measurement of "Wetting Power"

Several different proposals have been made for evaluating the wetting power of a filler metal—Fig. 7.

1. Spreading test with measurement of the contact angle α (Fig. 7-a).
2. Spreading test with measurement of the wetted area (Fig. 7-b).
3. Spreading test and determination of a coefficient $W = F \cos \alpha$, called "wetting index" (Fig. 7-b).
4. Determination of a so-called "penetration coefficient" (Fig. 7-c)

The following points should be noted:

Measurement of the Contact Angle. This method is not reliable because, as Bailey and Watkins also stated, there may be variations between the contact angle not measureable at fusion temperature, and the contact angle at ambient temperature. To this must be added the great dependence on the "roughness" of the surface which is difficult to measure.

The contact angle obtained in a experiment may frequently be measured directly by optical means. It may also be estimated by a method which does not involve any knowledge or assumption of the value of the surface tension of the liquid from measurements of the area covered by small drops. By any other method of estimation, the contact angle is derived in terms of the liquid surface tension, the value of which in the circumstances in which the contact angle is investigated may not be known.

Direct Determination of Surface Tensions. While it is clear that the surface tension of the surface is determined by its atomic arrangement, the value cannot at present be calculated with accuracy for given arrangements of atoms. In any case, in view of the possible concentration at surfaces of impurities which are below detectable limits when a bulk sample is taken, such an approach would have little practical value. The surface tension of the liquid surface in contact with the fluid face—either liquid or gaseous—may be measured directly, but those of the liquid metal/solid metal surface and of the solid metal/flux surface are not normally measured.

Surface Tension of the Liquid Metal/Flux Phase. Direct measurement of the surface tension of a liquid metal in contact with a flux phase is possible by several methods which are independent of the contact angle. Baily and Watkins mention values for a number of tin-lead solders in contact with hydrogen, or tin-lead solders with raisin fluxes, and finally surface tensions of tin and tin-lead solders of eutectic compositions in contact with raisin, zinc-amonium-chloride and stannous chloride fluxes.

Evaluation of the Wetted Area. These results are unsufficient if considered alone. Bailey and Watkins published values or Pb-Sn filler metals wetting copper sheets in the air and in vacuum—Fig. 8

Determination of the Coefficient "Wetting Index" $F = F \cos \alpha$. Feduska[14,21] reports on a great number of such tests and defines the wetting numerically. There is little known about the extension of the results and the applicability of the method. Nevertheless, this method is said to allow a fairly good choice.

Determination of α "Penetration Coefficient." Bailey and Watkins measured the filling of a capillary tube and determined a "penetration coefficient" for Pb-Sn filler alloys as indicated in Fig. 9.

Thermodynamical Calculation of Wetting

Bailey and Watkins have examined the wetting behavior of nine liquid metals (Ag, Sb, Te, Zn, Pb, Cd, Bi, Sn, Al) on five solid metals (Fe, Ni, Cu, Au, Ag) and their corresponding formation enthalpies. Results were as follows:

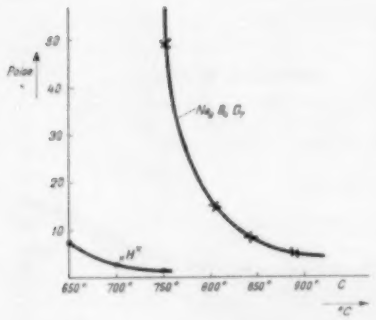

Fig. 10—Viscosity of flux "H" and $Na_2B_4O_7$ at various temperatures[21]

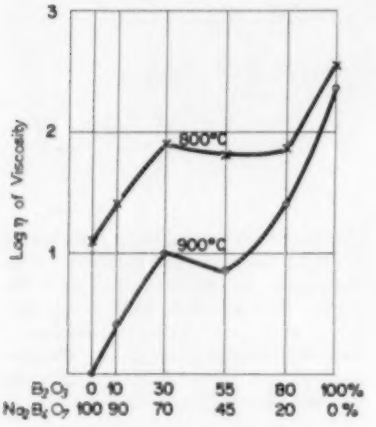

Fig. 11—Log η of the viscosity of B_2O-$Na_2B_4O_7$ Mixtures[24]

1. In the case of 17 pairs of metals, of which the formation enthalpy ΔH was negative, wetting occurred.

2. In the case of three alloy systems with a positive formation enthalpy, there was not wetting but "unwetting."

3. The eutectic Cu–Ag, Au–Bi and Ag–Bi systems have a positive formation enthalpy—that is to say that the formation of the alloy is endothermic with a maximum at the eutectic concentration. They wet their base plate above the eutectic temperature.

Schetz[21] shows that secondary reactions take place with the Cu-Ag, Au-Bi, and Ag-Bi systems; these reactions result in an exothermic alloy formation. Thus wetting becomes possible, and the apparent contradiction is eliminated.

Viscosity

Measuring Methods

Viscosity is expressed in g/cm-sec, i.e., in "Poise" or "Centipoise." Karman and Umstätter[22] and Köninger[23] describe a suitable rotation viscosimeter for the use in foundries; it is also suitable for heavy, nonferrous, and light filler metals. It allows the experimental ascertainment of the viscosity as a function of the temperature.

Viscosity of Filler Metals

There are very few values published about the viscosity of pure metals and alloys as well as of technical filler metals. According to the indications of the "German Copper Institute," viscosity should be between 3 and 5 g/cm. sec for copper filler metals.

Viscosity of Fluxes

Theoretically, the viscosity of a flux near work temperature should be so high that retentivity even on vertical walls is guaranteed for a long enough time during the brazing process. At the same time, it should be low enough to penetrate easily and quickly, together with the filler into the brazing gap.

Figure 10 shows the conditions for borax and a special fluorine containing flux "H".[21] Borax is sufficiently fluid above 800° C, while the fluorine-containing flux only needs a little more than 600° C.

Figure 11 shows the viscosity of various mixtures of borax ($Na_2B_4O_7$) and boroxide (B_2O_3) at 800 and 900° C between 0 and 100%.[24] The viscosity decreases as the borax in the mixtures is increased, i.e., these flux mixtures become more dilute the more borax they contain.

There are no test results published about the conditions of light metal fillers, high-temperature fillers, titanium alloys and noble metals.

Interrelationships

Relationships between Flux Viscosity and Wetting

0.02 Cm^3 flux with various compositions of borax ($Na_2B_4O_7$) and boroxide (B_2O_3) was placed on sheets (30 x 30 x 1 mm^3) with uniformly prepared surfaces of soft steel (0.1% C), copper and an austenitic chrome-nickel steel (18% chrome-8% nickel). The flux was then brought up to melting point simultaneously with 0.02 cm^3 filler metal in an electric oven set accurately at 980° C.

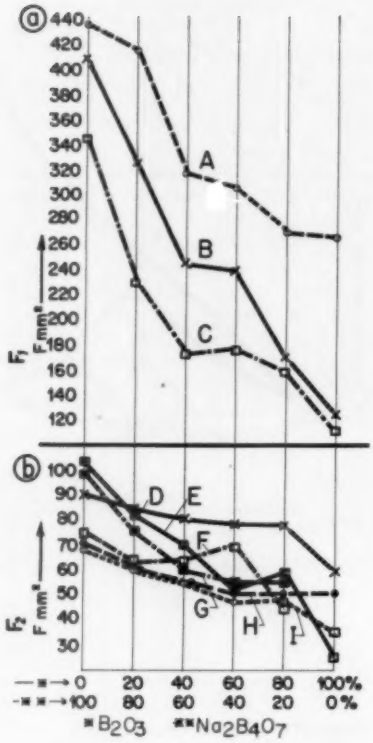

Fig. 12—Relationships between wetting and flux viscosity

(a) Surface of 0.02 cm^3 molten flux above the brazing alloy. Furnace temperature 980° C. Base metals: A—copper; B—steel; C—18 Cr – 8 Ni.
(b) Surface of the 0.02 molten brazing alloy beneath flux. Furnace temperature = 980° C. Brazing alloy. D—60 Cu – 40 Zn on steel; E—11% Ni-Cu-Zn alloy on steel; F—60 Cu – 40 Zn on 18 Cr – 8 Ni; G—11% Ni-Cu-Zn alloy on 18 Cr – 8 Ni; H—11% Ni-Cu-Zn alloy on copper; I—60% Cu – 40% Zn on copper (values of 10 tests each.)

After melting, each of the test-pieces was kept at a temperature of 980° C. In a first series of test a brass filler metal was used (60% Cu with 0.3% Si), and in a second series nickel-silver filler metal (47% Cu, 11% Ni, 0.3% Si, rem. Zn) was employed. When the test-pieces had cooled both the spreading area of the flux and the spreading area of the melted drop of filler metal were measured with a planimeter.

The upper part of Fig. 12 shows the spreading area for the flux mixtures on the steel, copper and chrome-nickel steel base metals. The spread is reduced as the viscosity of the flux mixture is increased. The lower part of Fig. 12 records the areas covered by the filler metal, i.e., those covered by filler metals Cu-Zn and nickel

Table 10—Spreading Areas, Sq Mm, of Flux Compound

Filler metal	On steel	On 18 Cr – 8 Ni	On Cu
60 Cu – 40 Zn	85	63	60
11 Ni-Cu-Zn	82	75	60

silver on the steel, copper and chrome-nickel steel base metals. In all cases the spread of these filler metals is also reduced as the viscosity of the borax-boroxide mixtures is increased.

The surface tensions of both filler metals when using flux are given in Fig. 4 at a brazing temperature of 980° C—550 dyn/cm for the brass filler metal and 680 dyn/cm for the nickel silver filler metal. Despite variations of more than 25% in the surface tension, the spread of both filler metals on copper, for instance, is practically the same with all flux mixtures, as shown in Fig. 12. The spread of the brass filler metal on steel and the spread of nickel silver filler metal on steel and chrome nickel steel is at its maximum when using pure borax—the flux with the lowest viscosity.

The essential components of the flux used for tests on the measurement of the surface tension were 80% borax and 20% B_2O_3. Figure 12 shows that the spreading areas of these flux compounds are as indicated in Table 10.

Except for the spread on chrome nickel steel, the spread of the brass and nickel silver filler metals with a composition corresponding to the filler metals in Table 1 is virtually the same, despite the different surface tensions. The size of the spreading area may be taken as standard for "wetting," since the same quantity of filler metal and an increasing spreading area causes the "wetting angle" to be reduced and "wetting" is improved.

If only half the amount of flux powder—0.01 cm^3—is supplied instead of the 0.02 cm^3 used in the previous tests, the spreads are reduced and wetting deteriorates. In other respects, however, the path of the curves is similar. On an average, the areas covered by flux are reduced as follows:

1. On steel base metal, by 20–25%.
2. On copper base metal, by 15–20%.
3. On chrome nickel steel base metal, by 10–15%.

The spread of the filler metal is also reduced as shown in Table 11.

From the above tests where both the amount of surface tension and the amount of wetting could be measured on comparable filler metals and fluxes, it must be concluded that "surface tension" cannot be admitted as a generally acceptable standard for "wetting" and that the base metals or alloys which can form on the boundary areas between filler metal and base metals can influence the amount of wetting even when similar fluxes are used. The amount of wetting is also affected by the quantity of flux.

Relationships between Wetting and Tensile Strength in Capillary Brazed Joints

Using the same filler metals and fluxes, the tensile strength of capillary joints brazed on steel with these materials was tested. Figure 13 shows the results. These indicate that the tensile strength of the gap brazed joint is reduced as the viscosity of the flux is increased or the spreading area (wetting) is reduced (Figs. 11 and 12). This statement

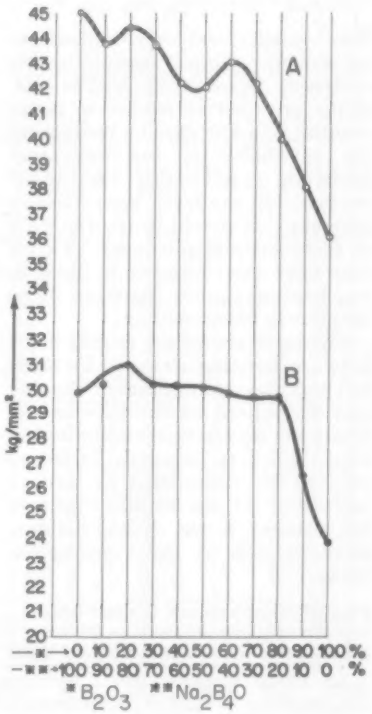

Fig. 13—Tensile strength of brazed joints on steel bars 30 x 8 mm^2, brazed with fluxes of various percentages of B_2O_3 + $Na_2B_4O_7$ (anhydrous). Clearance: 0.65 mm. A—Brazing alloy 11 Ni-Cu-Zn on steel 52; B—Brazing alloy 60 Cu – 40 Zn on steel 37 (10–30 tests per point)

Table 11—Spread of Filler Metal

Base metal	Decrease, %, of the spreading area 60 Cu – 40 Zn alloy	11 Ni-Cu-Zn alloy
Steel	21–25	10–20
Copper	5–10	5–10
18 Cr – 8 Ni	20–30	10–20

does not apply "quantitatively" for each individual point but only "qualitatively" for the general similarity between the individual curves.

Steel flats with a tensile strength of approximately 50 kg/mm^2 were used for the tests. The area of the brazing surface was 30 x 8 mm^2. The gap width before brazing amounted to 0.65 mm, corresponding to a filler metal gap of 0.15 to 0.20 mm after brazing.

Relationships between Spread (Wetting) and Tensile Strength of Gap Brazed Joints When Using Pastes Made of Borax ($Na_2B_4O_7$) and Boric Acid (H_3BO_3)

In practice, pastes mixed with water are widely used in place of flux powder. The use of a paste permits the spread to be increased by 30% with a flux of the same composition.

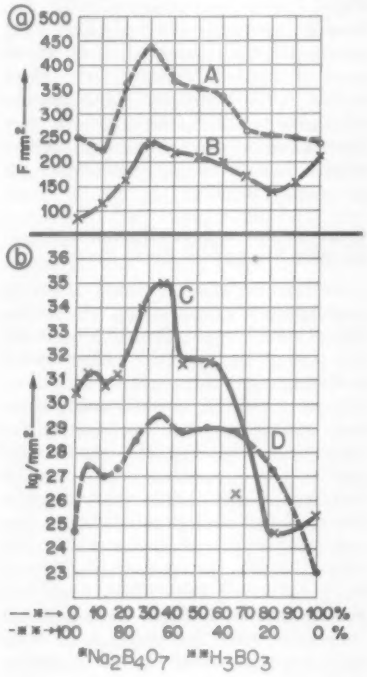

Fig. 14—Spreading (a) and tensile strength (b) of brazed joints with various aqueous flux-mixtures (H_3BO_3 + $Na_2B_4O_7$) (10 tests per point). A—Spreading of 0.02 cm^3 of alloy 60 Cu—40 Zn on steel T = 980° C; B—Same for 11 Ni-Cu-Zn-alloy; C—11 Ni-Cu-Zn-alloy on steel 37 clearance 0.25 mm; D—60 Cu – 40 Zn-alloy on steel 37

Spreading tests were made with water pastes mixed from aqueous borax ($Na_2B_4O_7$) and boric acid (H_3BO_3) and the tensile strength of the gap brazed joints was measured—Fig. 14. The spreading areas on steel are recorded in the upper part of Fig. 14; 0.02 cm^3 filler metal (brass filler metal and nickel silver filler metal) was once again used. Before the test, the steel plates (30 x 30 x 1 mm^3) were covered equally with the paste. The absolute values cannot be compared point for point with those of Fig. 12, since different batches of filler metal were concerned. This is equally true of the tensile strength, since in addition to the different batches of filler metal a steel with a tensile strength of 37 kg/mm^2 was used for the final tests.

It may, however, be determined that the maximum spread is achieved with a mixture of 30% borax and 70% boric acid. On both sides of this maximum, the spread is reduced. This difference arising from the powders seems to be attributable to changes in the pastes resulting from reactions in certain compositions during and after mixture with water.

If the curve of the spread—Fig. 14, top—is compared with the tensile strength curve—Fig. 14, below—it may be seen that these have a similar pattern. In other words, with these tests the tensile strength likewise depends on the amount of wetting, inasmuch as the tensile strength increases with an increase in wetting.

Relationships between Spread and Bonding Strength of Braze Welds

It has been determined that, in gap brazed joints using the same flux, there is a relationship between the size of the spread of filler metal (wetting) and the tensile strength of the joint. Such a relationship does not exist in *braze welding*. The lower part of Fig. 15 shows the size of the spreading areas (size of wetting); the upper part records the tensile strengths of both gap brazed joints and braze welds obtained from the respective fluxes. It is clearly discernible that the tensile strength of gap brazed joints increases with the amount of wetting, while with braze welding there is no relationship between the extent of wetting and bonding strength. It should be noted that the highest bonding strength was observed when using boric acid, which has a higher viscosity than borax. This can be readily appreciated, since in braze welding the

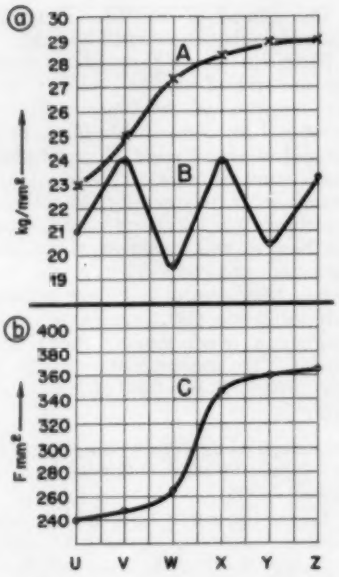

Fig. 15—Tensile strength (a) and spreading (b) in capillary joints and braze-welds with 60 Cu – 40 Zn brazing alloys on steel 37 with various flux mixtures. A—Mechanical resistance of the brazed joint (clearance = 0.25 mm; section: 30 x 8 mm^2); B—Conventional bonding strength of braze welds; C—Spreading of 0.02 cm^3 of 60 Cu – 40 Zn alloy on steel 37 kg/mm^2 (U = Borax-flux; V = Boric acid flux; W, X, Y, Z = flux-mixtures)

filler metal need not spread so extensively. Thus according to this evidence, fluxes with higher viscosity give better results in braze welding. In any case by comparing the suitability of the individual fluxes in gap brazing and braze welding, it may be seen that a different flux should be used in each of these brazing processes. Fluxes that have been successfully used in gap brazing cannot therefore be so effective in braze welding.

Figure 16 shows the relationships between bonding strength in braze welding, the composition of the flux and the spread of the filler metal. There are no relationships as before where bonding strength increased as viscosity diminished or wetting increased. It can be seen that now the reverse is the case: bonding strength rises as the viscosity increases.

Relationships between Contact Angle and Wetting Temperature in Braze Welding and the Effect of the Base Metal

In braze welding, the "wetting temperature"—that temperature which must be obtained on the surface of the base metal so that the filler metal bonds—can be lower than the solidus temperature of the filler metal, i.e., lower than the so-called "working temperature."[19] This wetting temperature can vary

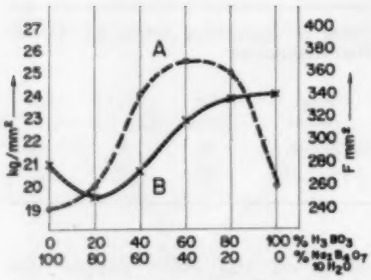

Fig. 16—Conventional bonding strength of 60 Cu – 40 Zn-alloy on steel 37 with various mixtures of $H_3BO_3 + Na_2B_4O_7 \cdot 10H_2O$. A—Spreading of the alloy (mm^2); B—Conventional bonding strength (kg/mm^2)

in brass and nickel silver brazing—for instance, between 780 and 900° C according to the method used. As shown from the tests summarized in Fig. 17, with steel as the base metal the contact angle diminishes almost rectilinearly with the rise in the wetting temperature, i.e., the "wetting power" is augmented. This straightforward interrelation no longer exists when cast iron is taken as the base metal. In this case the contact angle is hardly diminished despite the rise in temperature; above 900° C it starts to drop once again. The following causes can explain this phenomenon:

1. With a rise in temperature the formation of SiO_2 on the surface of the cast iron increases rapidly in conformity with van Hoff's law.

2. The SiO_2 cannot be changed into a lower melting reaction product by an acid brazing flux composed of $Na_2B_4O_7$ and H_3BO_3 as is the case with the basic fluxes in cast iron welding.

3. The SiO_2 can, however, be dissolved in the components of the brazing flux. This solution increases the viscosity of the flux melt and apparently also increases its melting point.

Here we have a case where the solution of components of the base metal in the flux increases the flux viscosity, in this way lowering the wetting power in the manner defined above. This example from another series of tests is additional proof of the relationships determined above between the viscosity of the flux and the amount of wetting.[25]

In summary it should be said that the test results clearly prove the importance of fluxes in brazing, particularly for the wetting and also the tensile strength of brazed joints. The results should also be a stimulus to further research in this field. Fluxes are as important in brazing practice as the filler metals themselves.

Effect of Surface Quality on the Tensile Strength of Brazed Joints

It has been shown above that in soft soldering the surface quality of the base metal has a decisive influence on wetting by the filler metal. Tests on the effect of surface quality on brazing indicate that the tensile strength of joints on steel made with brass filler metal (54% Cu, 46% Zn) can vary between 27.4 kg/mm² and 42 kg/mm² according to the surface quality—Table 12.[26,27]

As Table 12 shows, the tensile strength is lowest in the brazed joint with the "punched" surface. The "punched" surface cannot be compared with a sand-blasted surface, where the wetting is very effective. The punched surface contains large clefts over its area which interrupt the flow of the filler metal that consequently wetting deteriorates. The surface indicated in Table 12 was prepared in a crosswise pattern, i.e., by grinding ground with emery paper No. 100 at angles of 90 deg. It was thus provided with barrier capillaries vertical to the direction of filler metal flow. For this reason, the tensile strength with this surface is less than that very finely ground with emery paper 5/0. The flow of filler metal—the wetting—was also impeded on the coarsely filed and toothed surface, and the tensile strength was thus reduced. Capillaries running in the direction of filler metal flow which are not deeper than 0.3 mm have a "wet-promoting" characteristic.

Table 12—Influence of the Surface Quality on the Mechanical Resistance of a Butt Joint (Alloy: 54 Cu – 46 Zn)

Quality of the surface	Tensile strength, kg/mm²
Emery paper 5/0	41.8
Emery paper 100	34.8
Roughly filed	36.4
Punched	27.4
Roughened	33.6

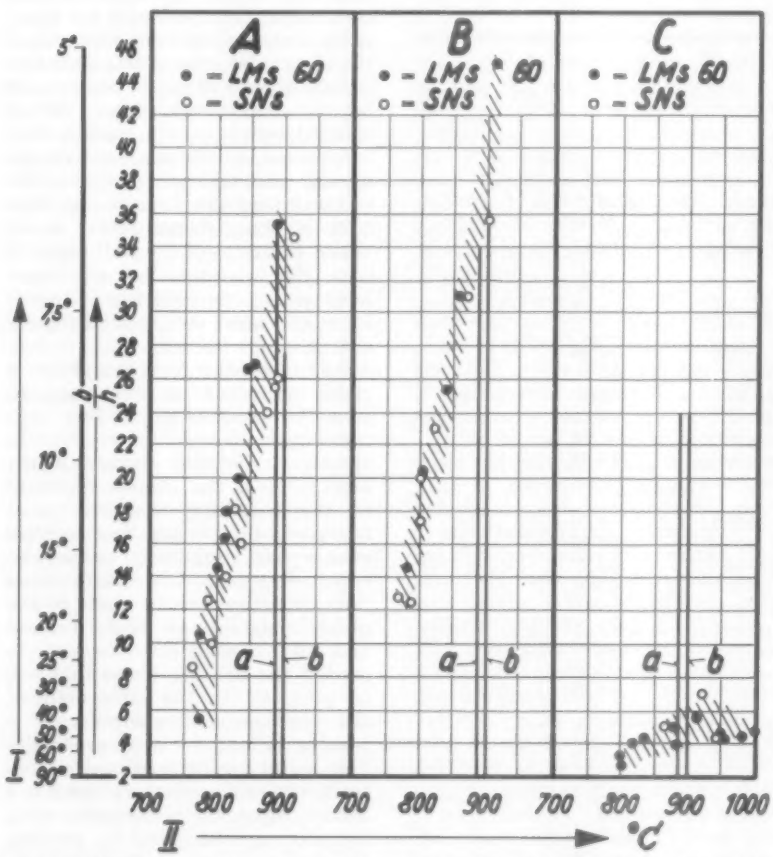

Fig. 17—Dependence of the ratio: clearance of the brazed joint to the height of the joint (b:H) on the wetting temperature. I = contact angle; II = wetting temperature of the base metal (before contacting the brazing alloy). A—on steel 8 mm thick; B—on steel 2 mm thick; C—on gray cast iron; a—working temperature of 60 Cu – 40 Zn-alloy; b—working temperature of 11 Ni-Cu-Zn-alloy. LMs 60 = 60 Cu – 40 Zn-alloy filler metal; SNs = 11% Ni-Cu-Zn-alloy filler metal

Summary

1. The physical concepts of "surface tension" of filler metals and fluxes do not appear to indicate generally valid and unequivocal amounts and values in brazing technology, since by definition they are only measured in air.

2. Experimental measurement of the surface tension of filler metals and fluxes was found difficult. Further research is necessary.

3. Moderate quantities of dissolved substances can have a favorable effect on the tensile strength and wetting of filler metals. Further systematic study of these problems would be helpful.

4. Neither surface tension nor viscosity are the decisive factors in the wetting of a filler metal. In addition to the characteristics and quantity of the flux used, the decisive processes are principally those taking place on the boundary area between filler metal and base metal; these up to now are largely unaccounted for. Further research is needed to understand this "interfacial tension."

5. A definite relationship exists between the viscosity of borax-boric acid mixtures and wetting, since the spread is reduced as viscosity increases.

6. On an increase of the viscosity of powder fluxes and reduction of the spreading area, the tensile strength of gap brazed joints is reduced. Or: tensile strength increases with a rise in wetting through the flux. When using aqueous paste fluxes, maximum values for wetting can be obtained; these provide the peak values for tensile strength.

7. The relationships are different with braze welds: Tensile strength seems to increase in conjunction with the increase in the flux viscosity.

8. On steel the contact angle of copper and filler metals drops as the temperature rises, i.e., "wetting power" is increased. This is not the case with cast iron, i.e., the contact angle remains virtually constant.

9. The tests indicate that the importance of flux in wetting and tensile strength is as great as that of the filler metal.

10. The tensile strength of gap brazed joints is greatly effected by the surface quality. Sand blasting or grinding with fine paper produce the best values.

References

1. Gautschi, R., Diss. ETH Zurich, Nr. 2665 (1957).
2. Kozakewitch, Chatel & Lage, *Rev. Metallurgie*, Nr. 2, 151–156 (1955).
3. Draht & Sauerwald, *Z. Anorg. u. Allgem. Chem.*, 162, 301–312 (1927).
4. Pohl & Scheil, *Z. Giesserei*, Bd. 431, Heft 26, 833–838 (1956).
5. Schatz, J., *Z. Schweissen und Schneiden*, Bd. 9, Heft 12, 527 (1957).
6. Miller, M. A., THE WELDING JOURNAL, **25** (2), Research Suppl., 109-s (1946).
7. Pelzel, E., *Berg. Hüttenmänn. Monatsh.*, **93**, 248 (1948).
8. Pelzel, E., *Ibid.*, **94**, 10–16 (1949).
9. Keel, *Zeitschrift für Schweisstechnik*, Bd. 51, 64 (1961).
10. Eucken, A., *Grundriss der Physikalischen Chemie*, Leipzig, 287 (1944).
11. Kubaschewsky and Evans, *Metallurgical Thermochemistry*, London (1958).
12. Bredzs, N., THE WELDING JOURNAL, **34** (10), Research Suppl., 508-s to 520-s (1956).
13. Sistiaga, J., and Leinpo, J., *Ciencia y tecnica de la soldadura*, Madrid, 1–9 (1960).
14. Feduska, W., THE WELDING JOURNAL, **39** (7), Research Suppl., 292-s to 300-s (1960).
15. Bailey and Watkins, "The Flow of Liquid Metals on Solid Metal Surfaces," *Brit. Inst. Metals*, **80**, 57–76 (1951–52).
16. Messing, Deutsches Kupfer-Institut, Berlin, 22 (1956).
17. Miller, M. A., THE WELDING JOURNAL, **20** (10), Research Suppl., 474-s and 475-s (1941).
18. Colbus, J., "Probleme der Löttechnik II," *Schweissen und Schneiden* Nr. 6, Sonderheft, 140–147 (1954).
19. Colbus, J., "Versuche zur Deutung der Bindevorgänge beim Löten," *Ibid.*, 10, Heft 2, 50–54 (1958).
20. Feduska, W., THE WELDING JOURNAL, **38** (3) Research Suppl., 122-s to 131-s (1959).
21. Schatz, J., *Z. Schweissen und Schneiden*, **7** (1957).
22. Karman und Umstätter, *Einführung in die Viskosität*, Berlin (1952).
23. Köninger, *Z. Giesserei*, Heft 28, 1557 (April 1960).
24. Landolt-Börnstein, 4. Band, 1. Teil, 634 (1955).
25. Colbus, J., "Messungen der 'Benetzungstemperaturen' beim Lotschweissen und deren Zusammenhänge mit anderen Temperaturbegriffen," *Zeitschrift für Schweisstechnik*, **48**, Heft 1 und 2 (1958).
26. Klought, W., "Löten von Stählen mit hoher Festigkeit," *Autogene Metallbearbeitung*, **36**, 237–248 (1943).
27. Colbus, J., "Gruindsätzliche Fragen zum Löten und zu den Lötverbindungen," *Konstruktion* 7, Heft II., 419–430 (1955).

A METHOD OF DETERMINING PRIMARY SOLID SOLUBILITY OF AN ALLOY

(Continued from p. 196-s)

with the exception of lithium do not. In addition, alkali metals do not take up elements of other groups in solid solution. This is due mainly to the difference in the electro-chemical nature since, if the metals differ widely in their electro-chemical nature—that is, one is very electro-positive where the other is electro-negative—there always is a tendency to form stable intermediate phases or intermetallic compounds at the expense of the primary solid solution. In such a case the solute atoms have a choice of entering the solid solution or an intermetallic compound. The tendency of the atom to enter the intermetallic compound increases as the electro-chemical difference increases. Hydrogen, nitrogen, carbon and boron are not strongly electro-negative, and with the transition metals they form true alloys. However, with more electro-positive metals they will form compounds of the nonmetallic type. When coupled with transition metals, they form intermediate phases of simple crystal structure when the radius of the interstitial atom is less than 0.59 of that of the metal atom. When the ratio of the radii exceeds 0.59, the interstices are no longer large enough to hold the nonmetal atom and more complicated crystal structures are formed.

Table 1

Element	Closest interatomic distance (atomic Diameter), Angstrom units	Periodic table	Electro-chemical factor	Axial ratio
Aluminum	2.862	2nd short period	+0.65	...
Barium	4.35	...	...	...
Beryllium	2.225	...	−1.0	1.57
Cadmium	2.979	2nd long period	−0.18	1.88
Calcium	3.94	...	...	...
Carbon	1.5	1st short period	−0.49	...
Chrome	2.498	1st long period	+3.5	...
Cobalt	2.506–2.511	1st long period	Ferro	1.62
Copper	2.556	1st long period	−0.086	...
Gold	2.884	3rd long period	−0.15	...
Iridium	2.714	3rd long period	+0.14	...
Iron	2.481–2.585	1st long period	Ferro	...
Lead	3.499	...	...	...
Lithium	3.499	1st short period	+0.50	...
Magnesium	3.196	2nd short period	+0.55	1.62
Manganese	2.2–2.7	1st long period	+9.7	...
Molybdenum	2.5	2nd long period	+0.93	...
Nickel	2.491	1st long period	Ferro	...
Palladium	2.75	2nd long period	+5.2	...
Platinum	2.775	3rd long period	+0.97	...
Potassium	4.627	...	...	...
Rhodium	2.689	2nd long period	+0.99	...
Rubidium	4.88	...	...	...
Silicon	2.4	2nd short period	−0.13	...
Silver	2.888	2nd long period	−0.20	...
Sodium	3.175	...	...	...
Strontium	4.31	...	...	...
Tantalum	2.860	...	...	...
Thorium	3.60	...	...	...
Tin	2.75–3.2	2nd long period	−0.25	...
Titanium	2.189	1st long period	+3.3	1.60
Tungsten	2.739	3rd long period	+0.28	...
Vanadium	2.632	1st long period	+5.0	1.86
Zinc	2.664	1st long period	−0.157	...
Zirconium	3.17–3.13	2nd long period	+1.3	...

Our investigations have shown that the primary solid solubility of an alloy can be determined by the atomic diameter of the base element in the alloy. Then the atomic diameter of the remaining elements must fall inside the plotted lines to form primary solid solubility. If an element does not fall inside these lines, reference can be made to the phase diagram of that element and the base metal element to predict the eutectic phase that will be present. In the same manner, the primary solid solubility of a brazing alloy in any particular base metal can be predicted. Generally where liquation is present in a brazing alloy, the elements forming liquation can be found by plotting the brazing alloy on an atomic diameter graph. The use of this information, therefore, can predict the presence of eutectic compounds that would be liable to cause trouble in welding or brazing.

Inspection and Measurements of Properties of Welds in Plastics

Nondestructive testing advances and a weld additive to prevent brittle fracture are described in paper sponsored by IIW

BY G. A. HOMES

Owing to the increasing use of plastics and welded joints of these materials, it appeared useful, for improving the quality of the welds, to detect and classify the inhomogeneities present in the welds of polyethylene, polyvinylchloride and methyl methacrylate.

Even inside blocks of plastics manufactured by press welding a series of sheets, it appeared that lack of homogeneity inside blocks were often at the origin of weld defects. The trouble is that such blocks are often machined, and faults are only discovered when machining—but at this moment a big amount of money has already been spent in salaries and the work is lost. This shows how important it is to inspect the original material by nondestructive testing.

On another side in many applications such as the construction of vessels and pipes for gas or water-supplies, plastics are welded. Therefore, different techniques are used: spot welding (by heated iron pieces or by dielectric losses heating), local polymerization of a fluid monomere (not practical), hot pressing and mainly torch welding (autogenous welding) with gas or electric torches. Depending on the care taken during welding, faults may occur in the welds. For this reason it appeared also useful in this field to develop nondestructive methods.

Radiography

Nondestructive testing appears as a basic tool for a better knowledge of the modern plastics and as a practical tool for quality inspection. Two methods were employed by the author's co-worker J. C. Bauwens and author in Belgium: radiography and ultrasonics.

Considering first X-ray inspection, the main difficulty in radiography arises from the high transmittivity of plastics toward X-rays, coming itself from the low atomic numbers (e.g., polyethylene: C and H) and generating low contrast in comparison with common radiography of steel). Many radiographs taken in the past had no meaning in that the absence of shadows of heterogeneities was badly interpreted as a sign of quality. In fact it was only an indication of a poor application of radiation to this kind of material. In short, common X-ray equipment is not at all appropriate for the inspection of plastics.

The difficulty of contrast has been successfully overcome by using a new prototype of X-ray equipment especially made for the purpose by a Belgian manufacturer—Fig. 1. This apparatus generates voltages from 1 to 50 kv adjustable to any intermediated voltage. The X-ray tube has a beryllium window and generates a wide angle beam in such a way that common pieces may be usefully irradiated at a distance of about 500 mm in a reasonable exposure-time. For examining butt welds in polyethylene about 7 mm thick, voltages of about 8 kv are used; exposure times of a few minutes are needed.

Under such conditions, a contrast sensitivity of 1% (expressed in thickness differences) is reached, even in the most transparent plastic —polyethylene. Results are better than the common sensitivity reached in radiography of steel. The equipment, itself, is light, easily handled, and safe.

For compensating irregularities in thickness at seams, a special paste was developed—Figs. 2 and 3. It has the same absorption coefficient as that of the material to be tested. The paste is easy to apply along the seam and avoids the machining of the welds in routine inspection. For checking sensitivity, image quality indicators (I.Q.I.) were made with a row of wires or ribbons of plastics, of increasing thickness.

Radiographs now are satisfactory and make it possible to detect the main inhomogeneities. Thus work was started on reassembling a collection of reference radiographs, inspired by the I.I.W. collection. Owing to the fact that the X-radiation is soft and the materials have small atomic numbers, the quality of the radiograph depends very much on the experimental conditions. Therefore, it was believed useful to be able to calculate quickly the optimum voltage (V) and the optimum exposure time (t). A theoretical investigation then led to use with a reasonable accuracy—that is, within the limits of thickness from 5 mm up to 15 mm.

It is possible to reach a contrast corresponding to 1% of the thickness, even for polyethylene. Such results are obtained for an exposure time (t) corresponding to a ratio between incident radiation (I_0) and transmitted radiation (I):

$$I_0 I = 500$$

A simple calculation shows that this condition needs the following one:

$$\mu \cdot x = 3$$

where x is the thickness of the material and μ the global absorption coefficient for the minimum wave length λ present in the spectrum.

So, for a given material, the voltage (V) must be such that μ equals $3/x$. Looking at a table or a chart to the curve giving μ as a

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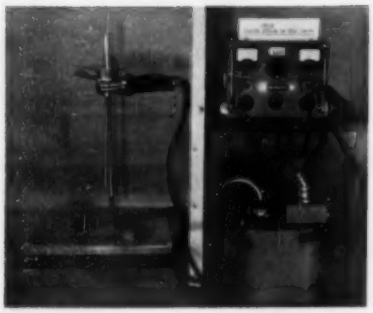

Fig. 1—Special radiographic equipment designed for the testing of welds in plastics at the request of the Belgian Committee for Solid State Investigation

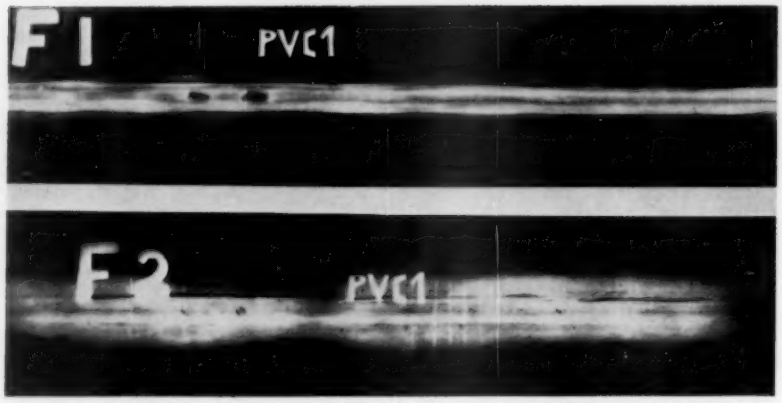

Fig. 3—Radiographs of a plate of welded polyvinylchloride without (F1) and with (F2) a special absorbing paste for compensation of thickness irregularities. The increase of contrast by the use of the paste is clearly visible

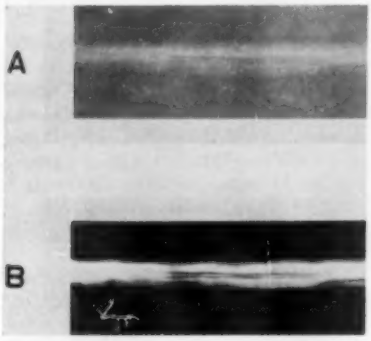

Fig. 2—Radiographs of the same weld in PE, with rough surface

A. Taken with a usual equipment at its minimum voltage of 20 kv.
B. Taken with the special equipment represented on Fig. 2, at the voltage of 8 kv. Contrast improvement is evident

function of λ, there will be only one value of λ corresponding to this value of μ. Such value of λ, when considered as a γ corresponds to a definite voltage, $V = 12\ 34/\lambda(A)$ (kilovolt). This is the correct voltage.

If one value of t for a voltage (V) is known by this way for one material and one thickness, any exposure time (t') for any other voltage (V') giving the same contrast (corresponding to $I_0/I = 500$) for any material in any thickness may be deduced from the relation:

$$\frac{t'}{t} = \left(\frac{V}{V'}\right)^2$$

Good agreement was found between theoretical considerations and practical results for any plastic checked between 5 and 20 kv—Fig. 4.

Ultrasonic Inspection

Two reasons suggested the development of ultrasonic testing: (*a*) detecting faults which could not be easily observed by radiography and (*b*) faster and cheaper inspection.

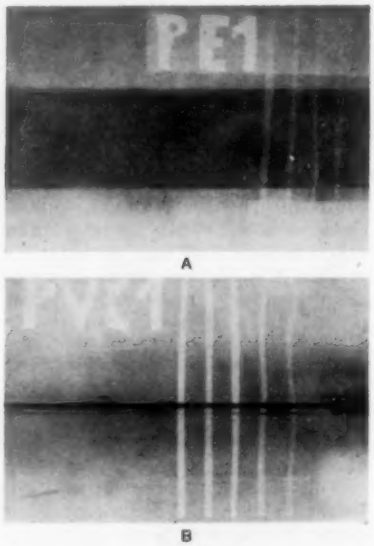

Fig. 4—Radiographs of flush butt welds in plates of 5 mm. × 2)

A. PE, film enveloped by paper; voltage, 7 kv
B. PVC film enveloped in paper; voltage, 20 kv

The main difficulty arises from the fact that high frequency elastic waves are strongly damped inside plastics. This occurs in such a way that common equipment may only inspect very small thicknesses by transmitting methods and are inefficient with echo methods used with beams at grazing incidences. As a penetration of about 200 mm is needed for inspecting weld seams with the echo scanning process, it was evident that special devices had to be developed.

It is known that damping decreases with frequency. Some people have suggested using waves of low frequencies (not far from accoustical spectrum). Such suggestions stayed speculative and did never, insofar as known to the author, lead to practical results. Of course, the resolving power decreases so strongly with frequency that this way was not the good one.

The first effort was to increase the transmitting power within the limits of a good insultation around the piezoelectric crystal, to use the usual frequency of 1 mc/sec, and to increase the sensitivity of the receiver. A systematical study of the noise arising from the background allowed an increase in usual sensitivity to many hundreds of times. The first prototype equipment was and is still efficient but not handable enough for common use in workshops and industrial yards—Fig. 5. So-called "turgescent probes," developed since 1948 were used. They consist of rubber envelopes containing water under pressure on the external face of the crystal. Such probes are more or less deformable and able to match any surface irregularity. The relationship of accoustical impedance probe and material is excellent. With this first prototype, faults were detected up to a depth of 150 to 200 mm; they were localized with an accuracy of a few millimeters.

In a second attempt, tremendous attenuation of accoustical waves in plastics was compensated by amplifying more an echo coming from far than a near one. Without having operated so, it would not have been possible to appreciate the importance of a flaw, because a small and near flaw would have generated a gigantic deflection suggesting a big flaw in comparison with a dwarf deflection coming from an important but far flaw.

Therefore, an exponential amplifier was developed. Its coefficient was adjustable to compensate ex-

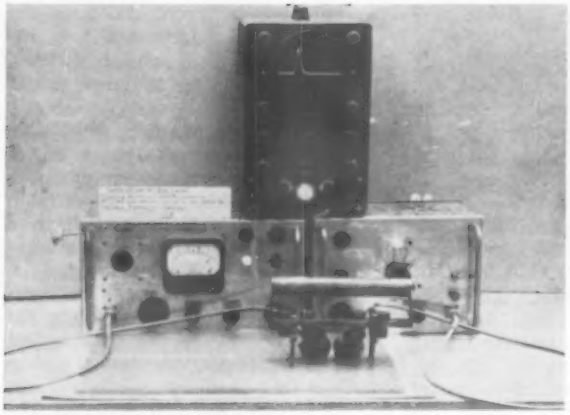

Fig. 5—Ultrasonic equipment for the testing of plastics. First prototype designed by the Belgian Committee for Solid State Investigation

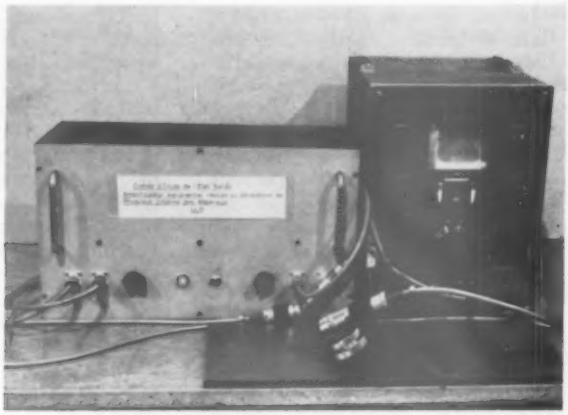

Fig. 6—Apparatus to be added to a usual ultrasonic equipment for enabling it to test plastics. Second prototype designed by the Belgian Committee for Solid State Investigation

actly the damping of the waves inside a definite material. With this unit, tests have been successfully carried out on polyethylene and polyvinylchloride samples with the same resolving power as in metal testing and up to the usual thicknesses.

In a third and last effort, improvements were made in the method and the equipment in such a way that, by using special and easily handled apparatus combined with ultrasonic equipment available on the market, it has become possible to test plastics as easily as metals—Fig. 6.

Special probes were developed to be used for plastics scanning with small angles beams. Two factors must be considered:

1. The material of the probe must have an acoustical resistivity appropriated to that of the investigated plastics, in such a way that the beams enter under a correct angle. For inspecting steel, we need probes in methyl methacrylate; here, probes in pure rubber are needed.
2. The form must be chosen in such a way that no dangerous echoes will be generated in the probe. The form is a kind of Christmas shoe.

Success was reached in producing a special paste for putting on the irregular surface of the seams, thereby avoiding the difficulties arising from diffusion of waves at this place. For testing spot welds, use was made of the transmittivity measurement, which is an efficient way of detecting any inhomogeneity in spot welds. A recorder was successful with ultrasonic equipment to register the results of automatic scanning.

Information Collected from Nondestructive Testing

The main *types of inhomogeneities* met in plastics—welded or not—are listed here; the symbol (R) indicates that radiography is the most convenient method and (U) refers to ultrasonics:

1. Lack of penetration—R + U (frequent).
2. Lack of adherence of restricted area, e.g., between seam and material—R + U (not very frequent).
3. Extended lack of adherence, of "lamination" type—R + U (not frequent).
4. Solid inclusions, coming mainly from dust on weld rods—R.
5. Isolated gas bubbles—R.
6. Clouds of bubbles—R + U.
7. Carbonized regions (overheating and mainly in polyvinylchloride)—R rather than U.
8. Cracks—R + U.
9. Faults at rod change—R and ± U.
10. Lack of adherence at the molecular scale, coming from a lack of diffusion of neighbor macromolecules. This defect is connected with structure alteration caused by chemical processes like oxidation. Detectable neither by R nor by U.

The last fault above is a very important one, because it does not appear by usual testing and because it decreases much the mechanical resistance. It is a very frequent fault in common welds mainly in polyethylene despite of the fact that it is possible to avoid it, but most people do not know of the existence of this kind of fault nor its physiochemical origin nor the way for avoiding it. For these reasons, this fault is considered further later in the paper.

The most common fault is "lack of penetration" which is detectable by X-rays when it is not too weak. It is also easily detectable by ultrasonics. This is very important, because lack of penetration is related to fatigue failure. Such a fault is often associated with a "lack of adherence," but this last one is not so easily detected.

Carbonized regions are a frequent fault in polyvinylchloride when welding with excess heat, but it is rather harmless despite of the fact that the nondestructive testing response is high.

Radiography and ultrasonics are *complementary methods*. Generally speaking, the second one is rather more sensitive although its interpretation is not as certain. The first one gives a typical document but is not as quick nor so cheap as ultrasonics testing. When possible, it is better to use one or the other of both methods depending of the suspected faults. In any case, the present state of perfection of nondestructive testing of plastics allows everyone to know the main kind of defects which may be present in welds and to detect them as easily as in metallic welds.

Concerning the specific *influence of the material*, the common faults in polyvinylchloride (PVC), high pressure (common) polyethylene (HPE), low pressure polyethylene (LPE) and methyl methacrylate are lack of penetration and lack of adherence at the molecular scale. (Both faults are avoidable.) Fine solid inclusions may be met when the weld was made without care.

Ordinary lack of adherence is

rather common in PVC but not in other materials. Carbonized area is specific to PVC and PMM; it does never exist in HPE nor LPE. Gas bubbles are more frequent in PVC and PMM than in PE. Spontaneous cracks are rare in any plastics. Practically speaking, they do not exist in PE. Faults at a rot change are frequent in PVC and rare in PE.

After having made typical welds with different kind of faults in different materials, work started on a collection of *reference radiographs and records of ultrasonic echoes' amplitudes*, for rough and flush welds. For rough welds, results are rather poor if the operator does not use the uniformizing pastes that are recommended. It is hoped to complete the collection and to publish an atlas.

Improvement of the Welds

Let us come back to the *lack of adherence at the molecular scale.*

As noted in the past, even in welds for which no inhomogeneities were detected by either soft X-rays or ultrasonic scanning, the mechanical properties were often poor and it was even sometimes possible to scratch out the full seam from the assembled joint.

In another way when the fracture surfaces of welds were observed with a microscope, local areas without weld were detected surrounded by welded areas. Both phenomena decreased or even disappeared if a fresh machining and a specific chemical etching were applied just before welding. In PVC, mechanical etching was never sufficient.

This suggested suspecting specific phenomena at the skin of plastics, and led *to analysis of the skin.* Used, on one side, were infrared absorption spectrography and, on an other side, chemical extractions from the superficial layer. Investigations have shown that the skin of plastics contains appreciable amounts of products arising from depolymerization and oxidation of the high polymers. Such products are responsible for the lack of adherence of the welds. The only way of joining the weld and the base material up to the molecular scale is thus to scratch out the altered skin mechanically or by means of a *swelling agent* (dichlorethane for PVC and trichlorethylene for PE).

A theoretical study of the *process of diffusion* of linear-macromolecules, which are the elementary constituents of the polymerized solids, shows that good mechanical properties arise from macromolecules which are so well diffused that they are embroiled together in solid bindings. If there is a lack of diffusion, the molecules lay in vicinity but without embroilment and the mechanical properties become poor.

Owing to the small diffusion coefficient of polyethylene, heat coming from the welding process is conveniently sufficient for generating diffusion in this plastic if the surfaces are cleaned and free from the superficial altered layer. In polyvinylchloride, on the other hand, the heat does not promote diffusion on a sufficient scale and assistance must be given to the diffusion process by a *solving agent* (cyclohexanone) added in small amounts to the weld.

This solving agent increases the diffusion coefficient and allows embroilment of the macromolecules, thereby improving the mechanical properties.

Summarizing, one may say that a *lack of adherence at the molecular scale* may frequently happen in welds of plastics. This arises from superficial alterations and from a lack of diffusion of the macromolecules. This fault decreases the mechanical properties. Unfortunately it cannot yet be detected either by X-ray or by ultrasonics. However, *it is easy to avoid it* and to *improve* the welds by:

1. Eliminating the skin of the rods and of the materials, just before welding, mechanically or with a swelling agent.
2. Adding small amounts of a judicious solving agent to the weld for increased diffusion.

Such improved welds have 100% of the base-material tensile strength in PE and 90% in PVC. These values must be compared to common welds in which 50 or 60% are the usual performance.

Mechanical Tests

The usual mechanical tests are applied to plastics and to their welds. These include the tensile test, bend test, torsion test, impact test and fatique test.

In many cases the *dispersion of results* is so high, arising both from the testing method and from heterogeneity in elaboration of the material, that data in the literature are not reliable. Progress was made when experts understood factors such as the necessity of operating in controlled atmospheres, steady temperature, and controlled speed

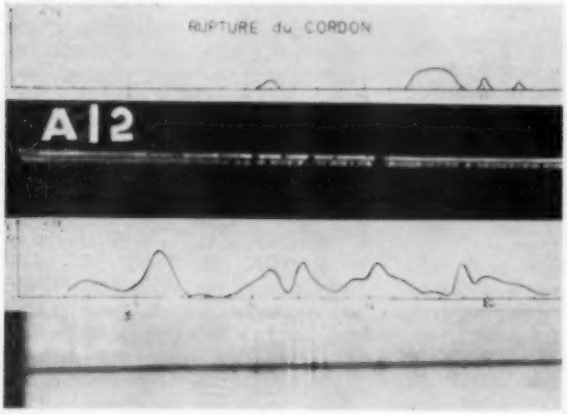

Fig. 7—Correlation between X-ray and ultrasonic testings. Plate coming out of a collection of reference documents elaborated by the Belgian Committee for Solid State Investigation

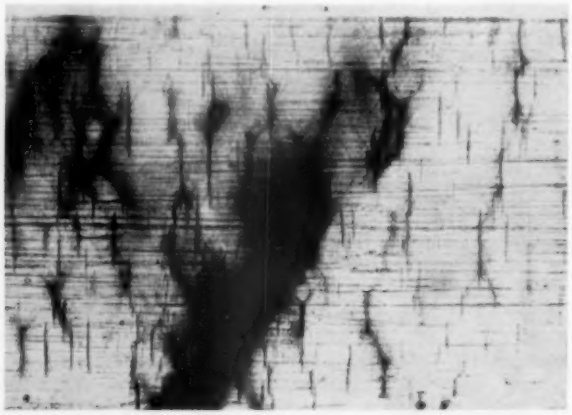

Fig. 8—Superficial cracks perpendicular to the traction axis and deformation bands starting from them, in a PVC test-piece submitted to tensile test. (× 40)

of deformation. Nevertheless, until now, attempts to get very reliable measurements for fatigue testing have not been successful.

After careful mechanical measurements or after observed practical behavior, attempts were made to correlate the mechanical properties to the inhomogeneities discovered by nondestructive testing.

As indicated in Fig. 7, it has been possible to show *statistical correlation* between mechanical behavior and the amount and kind of faults observed by nondestructive testing mainly for polyethylene and for ultrasonic testing. However, two facts were noticeable:

1. There are two such *cases* in which *the correlation is bad.*

2. Polymerized solids break down *sometimes with ductility but often with brittleness*, which underlines how it is inappropriate to call such materials "plastics." (They are elastic, but never plastic in the conditions of their use, and sometimes brittle. A metal like steel would be more logically called "plastic" than polyvinylchloride.)

Deviations in the correlation between mechanical behavior and nondestructive testing have a physical origin. They proceed from the nature of the deformation and fracture processes as well as from the sensitivity of these processes toward shape, orientation and (more or less) size of inhomogeneities. Even for "good"welds or even "good" base materials (in the usual sense of the word "good"), many very small inhomogeneities are present and influence the processes of deformation and fracture, generating brittleness. For explaining that, we must come back to fundamental considerations concerning strain and cracks.

Physical Laws Ruling the Mechanical Behavior of Plastics and Their Consequence

Co-workers, Mrs. R. Pankowski, and J. C. Bauwens believe with the author that plastics, like metallic materials, are subject to the following mechanical criteria:

1. *Criterium of deformation* of Huber, Heuky and von Mises. Under the influence of a single increasing stress σ, a plastic deformation generated at a definite point propagates as a cone. Its top lies at this point, the axis lies parallel to σ, and the half angle is 55 deg. Luders deformation bands in plates are, therefore, always inclined under 55 deg on the traction axis. They exist in any plastics at room temperature. For methylmethacrylate the temperature must, however, exceed 80° C. Intersections of the cone and any surface is always a conic; this can easily be observed in practice. If such deformation ends by a fracture, this last is of the "cup and cone" type.

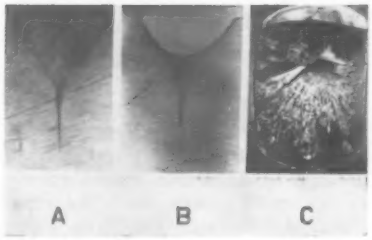

Fig. 9—Cracks in PVC

A. Generation of an internal crack in a specimen submitted to bending. (×80)
B. Same process in a notched specimen submitted to tensile test. (× 35)
C. Facture surface of a notched specimen submitted to tensile test, with typical brittle aspect. (× 12)

2. *Criterium of rupture.* A brittle fracture may start from inside in a material possessing ductility in the vicinity of the place where the *two* following *conditions* are *simultaneously* fulfilled:

$$\tau_{max} \geq \tau^* \quad \text{(criterion of Guest)}$$
$$\text{grad } \tau_{max} \geq C \quad \text{(our additional criterion)}$$

where τ_{max} is the highest shear stress, τ^* is a critical value connected with the kind and state of material, and C is a critical value connected to the kind and state of material, test conditions and temperature.

3. Plastically deformed regions exert stresses on their boundaries. Fracture starts if it exists a process connected with the plastic deformation, which tends to stop this one in the regions of decreasing tensions. We may yet understand that stress gradients and any local inhibition of plasticity have a big influence on the start of an internal crack. Therefore, *small inhomogeneities may exert a big influence* on the final fracture. Internal cracks occur in PVC for this reason. The value of the gradient generated by a local fault does not depend much on its volume but on its form and orientation.

4. Plastics deformation is only possible if it concerns a whole volume superior to a critical volume V_0. V_0 is rather big in PVC, because of the embroilment of the macromolecules; V_0 is also big in PMM; V_0 is smaller in Ziegler low pressure PE; V_0 is very small in high pressure common PE, because the macromolecules may slip easily and not much embroiled.

The small value of V_0 for HPE is the reason why the brittleness of this material is very lower than that of PVC and why the correlation between nondestructive testing and destructive tests is better.

5. Transverse superficial cracks start in PVC and PMM but not in PE submitted to tension below the yeld point. They stop after a critical extension of a fraction of a millimeter, because then plastic deformation is generated at their ends. If superficial claws are present, such cracks are distributed along them.

6. All plastics present a yield point (for MP, the temperature must exceed 80° C) arising from the fact that overstresses exist at the boundary of plastically deformed regions. In PVC, plastic deformation causes the disappearance of the yeld points. However, aging under tension at room temperature generates a progressive reappearance of the yeld point, caused by an increase in lateral order of the macromolecules.

7. Brittle fracture occurs when the speed of propagation of a crack exceeds a critical value. This may be observed in PVC, PMM, LPE but not in HPE.

8. When surface flaws are not deep enough or when the specimen thickness is too small, brittle fracture will not start.

9. In the bottom of superficial cracks, plastic deformations may happen and end with internal cracks.

10. The internal inhomogeneities cause local stress concentrations and stress.

11. When a material like PVC is submitted to a stress gradient, plastic deformation generates increasing overstresses in decreasing volumes as long as it propagates toward regions of small stress. Then internal stresses start. That is the reason why a notch submitted to external stresses generates a stress gradient and causes internal cracks.

We understand now why small defects suffice to generate superficial cracks—Fig. 8. It is also understood why deformation bands propagating in a region where a stress gradient rules may generate internal cracks; a notched rod submitted to tensile test undergoes a stress gradient in the neighborhood of the notch and a crack starts there—Fig. 9.

Propagation of Brittle Cracks

It has been proved that, during

decohesion, separating molecules generate transverse shock waves which can generate new molecular decohesion farther in the wave plane, and so start a chain reaction.

The shock wave's amplitude is all the bigger as the rate of molecular decohesions by time unit is great. This amplitude is proportional to the area of the new surfaces generated by time unit (resulting from successive decohesions) and thus proportional to the speed of propagation of a crack. It can be seen how the influence of the shock wave becomes predominant when the speed of propagation is high, and vice versa. By such mechanism, a crack may be the origin of a sudden and brittle fracture.

Conclusion

After having analyzed the physical mechanism of deformation and fracture in the plastics, one can understand the specific influence of definite types of inhomogeneities—even small sizes—on the mechanical behavior. One is now able to understand that the contradictions met sometimes in the correlation between nondestructive testing and mechanical behavior are more apparent than real.

The nondestructive inspector must thus be rather severe, and the welder must take the greatest care to avoid even the smallest faults.

The addition of a solving agent, in small amounts, in a weld, generates an easier development of plastic deformation and so reduces the danger of a brittle facture. When this danger is avoided, the conclusions of nondestructive testing are in better agreement with those of mechanical tests.

Acknowledgment

These researches, undertaken in cooperation with J. C. Bauwens, were financially supported by the universities, the Belgian institute IRSIA, a group of industrials and the Belgian Institute of Welding.

Many thanks must be expressed to these people and institutions.

EUROPEAN WELDING RESEARCH

(*Continued from page 209-s*)

welding machines for welding a blast furnace shell is described.

• A pistol with graphite electrode is used, instead of a welding torch, to spot-heat a welded part to eliminate buckles. The principle of resistance heating is applied.

Production Welding

The July 1960 issue of the Russian magazine *Svarachnoe Proizvodstvo* contains the following items:

• The transfer coefficient of alloying elements from sintered or water-glass-bonded, submerged-arc flux to Type 321 weld metal was determined. The coefficient for chromium was 0.60 for the sintered flux and 0.90 for the bonded flux.

• Ultrasonic welds in aluminum—3% copper alloy sheets $^1/_{16}$-in. thick had as high fatigue strength as unwelded base metal. The static strength decreased to 40% of room-temperature value when the testing temperature was raised to 480° F.

• A study of projection-welding steel $^1/_4$-in. thick showed that the same amperage should be used as for spot welding. The cracking and shrinkage cavities in the nuggets could not be eliminated by increasing the electrode pressure.

• Increasing the electrode diameter from 14 to 20 in. in the resistance welding of steel tubing 0.59-in. diam, $^1/_{16}$-in. wall allowed an increase in welding speed without increasing the current.

• The carburized and decarburized zones along the fusion line of butt welds in 0.30 C, 0.83 Cr, 0.16 Mo steel welded with electrode containing 0.18 C, 4.40 Cr, 0.42 Mo, 0.14 V lowered the short time and creep strengths.

• Pulsating tension fatigue tests were made on butt, lap and fillet welds made with 0.079 in. electrode and argon in aluminum—6% magnesium alloy $^3/_8$- and $^3/_4$-in. thick. At 5 million cycles the fatigue strength was 13,000 psi for base metal, 8500 psi for base metal with a hole, 7000 to 8500 psi for butt welds, and as low as 2800 psi for lap and fillet welds.

• The deep penetration attainable with lime-fluorspar-covered electrodes at high currents was utilized to rivet weld three steel plates together up to a thickness of 1 in. The electrodes were $^3/_{16}$- or $^1/_4$-in. diam, and were used at 700 to 1000 amp.

• Resistance-seam welding was used to weld lap joints in Type 321 stainless steel tubing $^3/_8$- to 1-in. diam, 0.025 to 0.079 in. wall. It was necessary to control dimensions closely, and to employ low welding speeds with long off times. For tubing 0.87 × 0.055, 13,000 amp was used, 3 cycles on, 38 cycles off, 850 lb pressure, 2.4 ipm travel speed.

• Worn steel forming rolls 4-ft long, $15^1/_2$-in. diam were surfaced with a deposit containing 0.55 C, 2.0 Mn, 8.8 Cr, 0.07 Ti, 72 Shore hardness by means of a $^5/_{32}$-in. mild steel electrode and a bonded submerged-arc flux containing 43 limestone, 11 fluorspar, 16 ferrochromium, 11 ferrotitanium, 5.5 ferromanganese, 2.5 ferrosilicon, and 11 chrome ore, bonded with sodium silicate.

• The covering of an electrode for hard surfacing hot stamping dies contained 20.5 $CaCO_3$, 30 CaF_2, 24 Fe-W, 15 Fe-Ti, 7 Fe-Cr, 2 Fe-V, 1 Fe-Si, 0.5 graphite bonded with water glass. The deposit contained 0.35 C, 8.5 W, 2.5 Cr, 0.35 V.

• An iron-powder electrode for welding steel was developed that deposited 3.4 lb of weld metal per 100 amp per hr. The coating contained 9% hematite, 8.7% granite, 8.15% ferromanganese, 1.35% starch 1% cellulose and 72% iron powder and was bonded with sodium silicate.

• Pressure-butt welds were made in 5% magnesium-aluminum alloy in sections up to $15^1/_2$ sq in. at 840° F and 170,000 psi pressure. The welds had 40,000 psi tensile strength and 120 deg bend angle.

A Solution Adopted in Some Difficult Applications of Flash Welding

Paper sponsored by IIW describes outcome of investigation on the flash welding of cast iron and heat-resistant high-chromium nickel alloys using automatically controlled motor-operated upsetting

BY EVERT BYLIN

ABSTRACT. An investigation was conducted on the flash welding of cast iron as employed for joining flanges to centrifugal-cast pipes and as applied to creep and heat resisting high-chromium nickel alloys with the basic analysis of 20% Cr, 0–20% Co, 70–50% Ni, 5% Fe and 5% Al + Ti + Si, used in jet engines. The welding was performed in a machine with automatically controlled motor-operated upsetting whereby the upsetting speed is considerably lower than that used in hydraulically operated machines.

The investigation proved that the flash welding of cast iron is possible provided accurate control of the upsetting stroke in connection with low specific upsetting pressure is maintained. The low upsetting speed provides for upsetting without impact and with exact length of upset travel, and the risk of destroying the crystal structure is then eliminated. With the procedure described, cast iron with rather great variations in analysis is readily weldable.

In the case of creep resisting alloys, it has been proved that a considerably lower specific upsetting pressure than required with hydraulic upsetting can be used with the described process due in part to the possibility of controlling the upset travel exactly and due partly to controlling the current during the upsetting and the possibility of breaking the current at the most suitable moment.

Introduction

In connection with the work in Commission III regarding collection of flash welding data as a first step to compiling process recommendations, a Swedish working panel decided to study the mechanics of upsetting more closely. The panel consisted of H. Wangsjo and G. Ekberg* besides the author. It assumed that close control of the platen travel, of the temperature and the heat distribution in the workpiece would be a critical factor for a good result when flash welding materials which are considered difficult to weld by this method—Fig. 1.

Materials chosen for the investigation were cast iron and one of the

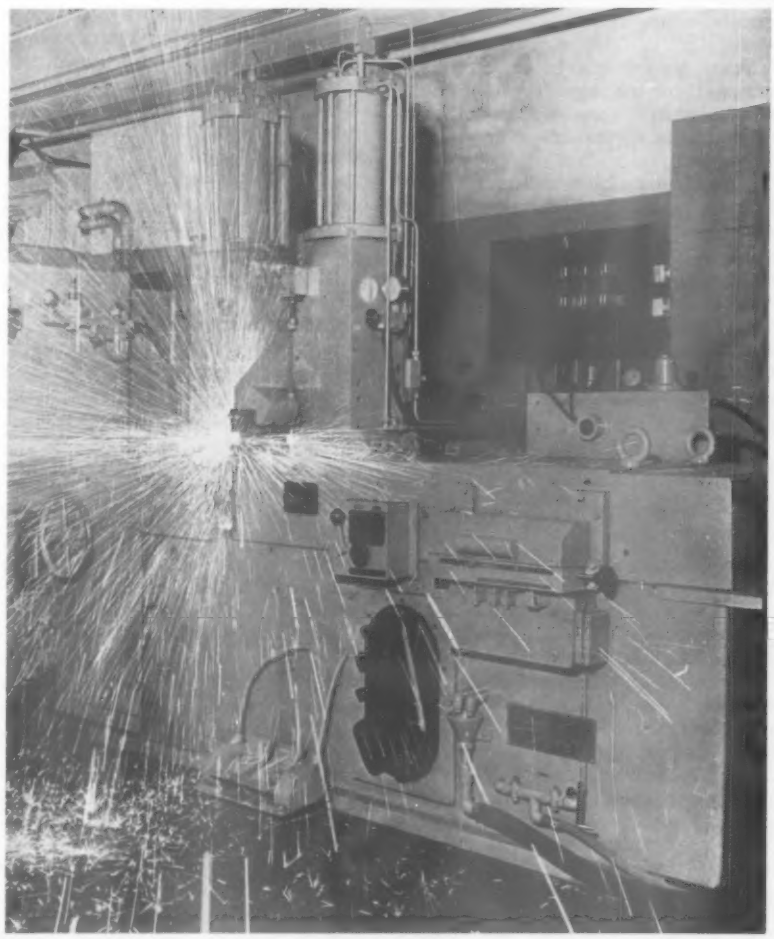

Fig. 1—Flash welding test set-up

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IIW paper presented at AWS 42nd Annual Meeting held in New York, N. Y., Apr. 17–21, 1961.

* H. Wangsjo is Head of Resistance Welding Research at Aseasvets (Aktiebolaget Asea Svetsmaskiner), Stockholm, and G. Ekberg is Head of the Welding Laboratory of the same company.

heat-resistant high-chromium-nickel alloys with the basic composition of 20% Cr, 0–20% Co, 70–50% Ni, 5% Fe and 5% Al + Ti + Si, used in aircraft jet engines. These materials must be considered as difficult to flash weld. The flash welding of cast iron comes into the picture in connection with the manufacture of centrifugal-cast iron pipes for sewage systems. Such pipes cannot be provided with the necessary flanges in the casting operation due to the considerable shrinkage which takes place during solidification and cooling and which would cause the pipes to crack when the molds prevented the flanged tube from shrinking freely. The flanges must, therefore, be fitted in a subsequent operation.

The brittleness of the cast iron results in low resistance to impact, especially in hot condition, and requires that special attention must be paid to the upsetting so that this operation can be performed without the crystal structure being damaged.

The main problem arising in connection with flash welding heat-resistant materials is that the weldability often decreases with improved resistance to heat.

This paper describes the process used for the tests and presents an extensive extract of the laboratory reports prepared by Messrs. Wangsjo and Ekberg during the investigation.

Upsetting Pressure in Relation to Physical Properties of the Material to Be Welded

As mentioned, an investigation of the experience gained in various countries has been carried out by Commission III—Resistance Welding—of the International Institute of Welding as to the specific upsetting pressure required for mild steel and certain alloy steels. This investigation shows that the upsetting pressure increases with increasing contents of certain alloy members and increasing strength.

An important condition applying to this statement is that a high platen speed is used during upsetting. The recommendations for flash welding settings, compiled by Commission III,[1,2] are adequate when welding mild and low-alloy steels. When welding the chromium-nickel-alloys dealt with in this paper, however, the consequences would be giant size machines for moderate cross sections; furthermore, there remains the problem of whether or not acceptable welds could be obtained under working conditions. This is one of the reasons for deciding to study a different program of platen movement than usually employed.

Various Methods Used to Execute the Welding Operation

Flash welding as practiced in America generally differs from the way it is executed in Europe. In America, welding without preheating or with manually governed preheating is very common. In Europe, on the other hand, welding with automatic preheating is prevalent practice.

Welding data for flash welding, as normally found in the literature, in general refer to machines which are cam- or hydraulically-operated and which usually work with direct flashing or sometimes with manually governed preheating. As described here, a system with automatic preheating is now in use in Sweden. Subsequent discussion centers on the theory of this method, especially as applied to cast iron and heat-resistant high-nickel alloys. Certainly, the process can be applied to all common steels and—sometimes with certain modifications—to nonferrous metals.

Preheating and Flashing

The flashing is sometimes preceded by a preheating and is always followed by an upsetting during which the welding proper is performed. Preheating and flashing are only intended to create suitable conditions for the upsetting.

A condition for obtaining a flashing is that the faying surfaces are, to a certain extent, uneven. When the components are brought together and the secondary of the welding transformer is short circuited, the current is flowing through only a few, limited-contact points. If the current is sufficiently high, these contact points will be momentarily heated, causing the material at these points to melt and partially evaporate. This results in violent expulsion of molten metal. Craters will then be formed in the faying surfaces at the spots where the contact points existed. When the surfaces are brought further together, new contact points are created in other places, and the process just described is repeated.

The unevenness of the surfaces is maintained by the formation of craters. The expulsions occur at very short intervals—several expulsions for each half cycle of the a-c current wave. This gives the impression of a continuous process. During the flashing, the faying

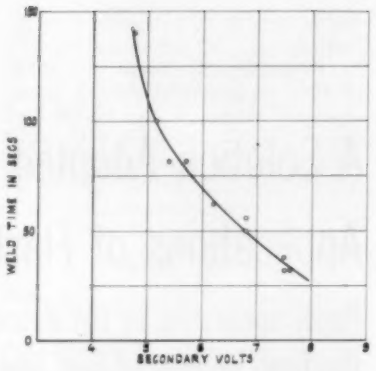

Fig. 2—Weld time for various welding voltages when welding a cast iron tube of 2300 mm² weld section. Most suitable weld time: 40 to 50 sec

surfaces are enveloped by evaporated metal which prevents air from coming in contact with them. The risk of oxidation of the faying surfaces is thus eliminated. As a result of the flashing, the faying surfaces are being fitted to each other. As the contact points are rapidly transferred across the surfaces the heat will be uniformly distributed.

Thus, the condition for the flashing to start is that so much heat is developed at the faying surfaces that they attain melting temperature. This can be made in different ways. One method is to choose a ratio between advancing speed and secondary voltage such that this condition is directly fulfilled, i.e., the process is started at low advancing speed and high secondary voltage. Another solution is to shape the faying surfaces so that the process is started with smaller faying surfaces; this means that lower secondary voltage can be used.

By means of both these methods, flashing can be started directly and a heated zone of sufficient depth for securing a correct upsetting is obtained by the flashing. The flashing travel must be rather long, and a certain acceleration during flashing and according as the temperature increases is often provided—or else the secondary voltage is decreased.

A third method is to use preheating, whereby constant speed and constant voltage are used. In order to concentrate the heat to the faying surfaces, repeated short contact moments are caused to occur. Due to the high and varying contact resistance, the major part of the heat is developed at the faying surfaces proper. Finally, such a temperature is obtained at the faying surfaces that the heat, which is being developed, is sufficient to

start and maintain flashing. During the flashing the advancing speed may be either constant or accelerating.

Upsetting

The object of the upsetting is to:

1. Stop flashing.
2. Bring the faying surfaces together.
3. Squeeze out molten material.
4. Deform the uneven faying surfaces so that a close contact is obtained over the entire surface, also where craters have been formed during flashing.
5. Produce a pressure such that tensile stresses cannot occur when weld and work piece shrink during cooling.

As the craters become larger and deeper, the higher is the secondary voltage. As greater upset travel is required, the higher secondary voltage is used.

When the faying surfaces are pressed together during upsetting, a certain mechanical resistance must be overcome. The pressure required for this purpose depends on the strength of the material in hot condition and on the distance the material must be moved to squeeze out into the upset fin.

The upset force is thus determined by the properties of the material, the temperature gradient, and shape and size of the workpiece. Obviously, one and the same workpiece can be welded with one and the same upsetting travel at various upsetting forces (depending on the temperature), *and a correct upset travel is thus more essential than a predetermined upsetting pressure.*

Thus, a solution which is not far to look for is to base the upsetting process on setting of the upset travel. This method is also common for all mechanically cam-operated machines.

Machines exist wherein the upset travel is stopped when a predetermined upsetting force has been attained. With this method, the upset travel will be uncertain and depend on the heat conditions at the faying surfaces. As the upsetting force is proportional to the cross-sectional area of the weld, it is difficult to cover a great area range with such a machine since it is possible to measure the upset force with sufficient exactitude only within a limited force range. Further, it is very difficult or impossible to measure the real upsetting force for hydraulically operated machines with high upsetting speed where consequently the upsetting time is short.

A high upsetting speed means that the inertia of the movable platen will be very high, and it will be difficult to limit the upset travel in the case of small welding sections which cannot themselves absorb this inertia.

During the short upset time, the welding current may often be switched off at a moment which must be determined with regard to the kind or type of work piece. It may be a question of a few hundredths of a second, and it is easily understood that this may be difficult to manage in a practical manner.

The resistance to deformation at upsetting also depends on the speed. As an example, resistance may be twice as high at a speed of 300 mm/sec as at 20 mm/sec.

During upsetting a deformation of hot metal occurs. In general, a heavy deformation does not cause any inconvenience in that most materials can endure it without cracking. For some materials a certain amount of care must be observed. This applies to cast iron which can stand only insignificant elongation and to materials rich on segregations where the segregation streaks by heavy upsetting may be oriented across the longitudinal direction such that they cause a notch effect. Sometimes, slag inclusions without any determined orientation may flatten out and be finely dispersed in the weld, causing a poor bonding of the weld.

Automatic Machine Control

From the foregoing it is evident that the actual problem requires an accurate control of the entire welding process. As described there, this is accomplished using a system with automatically motor-operated platen whereby it is possible to obtain a good control of all stages in the welding operation. In comparison with hydraulic operation, this system is distinguished by an automatic preheat control which is very sensitive and permits a wide cross-sectional range for a given machine size. The weld time is automatically accommodated to preset welding input, and the latter can be chosen with regard to available network power and the production requirements. As an il-

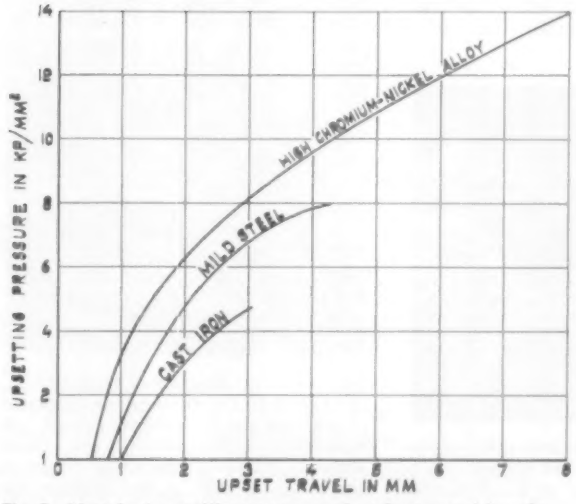

Fig. 3—Absorbed upsetting pressure at various upset travels

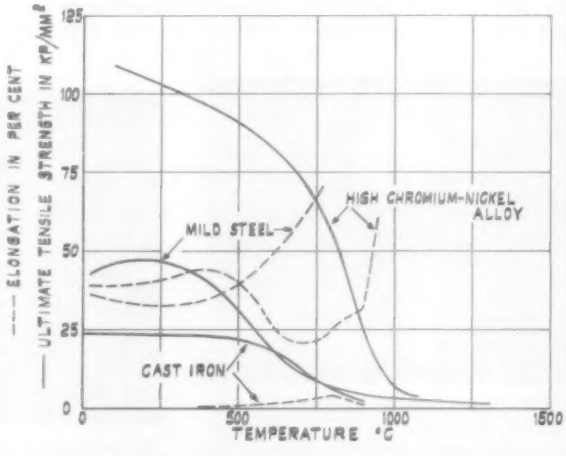

Fig. 4—Ultimate tensile strength (full line) and elongation (dashed line) for mild steel, cast iron and high-chromium-nickel alloy at various temperatures

Table 1—Physical Properties of Materials

Material	Mild steel	Cast iron	Nickel alloy 80
Specific weight, kg/dm³	7.86	7.2	8.25
Melting temperature, ° C	1450	1150	1375
Elongation at 20° C × 10^{-6}, ° C	12	12	11.9
Heat conductivity at 20° C, cgs units	0.14	0.11	0.029
Specific heat at 20° C, cgs units	0.11	0.10	0.11
Specific resistance at 20° C, ohms/mm²/m	0.13	0.90	1.24
Temperature coefficient	0.005	0.0019	0.00005

Table 2—Analysis of Materials, %

Material	Cast iron	Nickel alloy No. 75	Nickel alloy No. 80	Nickel alloy No. 90
C	3.5	0.08–0.15	0.1	0.1
Si	1.5–2.7	1.0	1.0	1.5
Mn	0.3–1.0	1.0	1.0	1.0
P	0.2–0.6	...	...	...
S	0.05–0.25	...	...	...
Fe	Bal.	5.0	5.0	5.0
Cr	...	18–21	18–21	18–21
Ni	...	Bal.	Bal.	Bal.
Ti	...	0.2–0.6	1.8–2.7	1.8–3.0
Al	...	...	0.5–1.8	0.8–2.0
Co	...	...	2.0	15–20
Cu	...	0.5	...	...
CC[a]	78–88	...	...	...

[a] Free graphite

lustration of the power question, Fig. 2 shows how the weld time varies with the secondary voltage at welding of cast iron tubes with 2300 mm² cross-sectional area. A suitable value for the weld time is, in this case, 40 to 50 secs.

The most important difference compared with the hydraulic operation is, however, that the upsetting is made at a rather low speed and that the platen travel is braked electrically so that an exact setting of the upset travel is possible without transmitting the inertia of the platen to the workpiece or to mechanical stops (dogs).

The unit operating the platen is a d-c motor connected to a Ward-Leonard set with separately excited generator. By variation of the generator excitation, various motor speeds can be obtained; by reversing the generator polarity, the direction of rotation of the motor can be reversed. During welding, the platen motor and the generator are electrically connected to each other; by using low excitation, a low platen speed is obtained for preheating and flashing. For upsetting, the generator is excited to full voltage and high motor speed is consequently obtained.

At the completion of upsetting, the motor is electrically braked by short-circuiting across a suitable resistance while the generator is simultaneously de-excited. As all regulation is made in the field circuits of the generator, the control effects are small and no mechanical couplings are required. Acceleration and retardation of the driving motor will also be uniform

During welding, the accuracy in platen travel is such that the final length of a workpiece can be predetermined with a tolerance of ±0.1 mm for 2000 mm² weld section and abt ±1.0 mm for 25,000 mm² weld section.

The direction of travel of the platen is during preheating, and flashing is governed by a voltage relay connected across the elec-

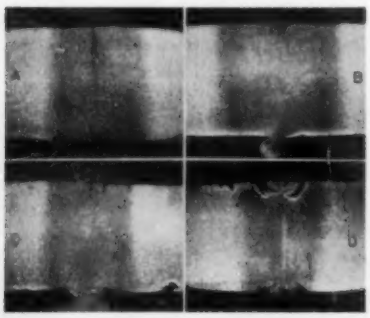

Fig. 5—Macrophotograph showing formation of superficial cracks in cast iron when the upset travel is increased. The upset travel for A = 0.9 mm; B = 2.2 mm; C = 3.2 mm; and D = 4.3 mm. Etching: 1% HNO_3. × 2

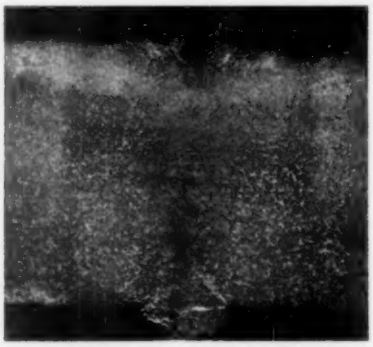

Fig. 6—Steadite in cast iron weld—same section as in Fig. 5C, but etched in 5% HNO_3 and magnified. × 5. (Reduced 35% on reproduction)

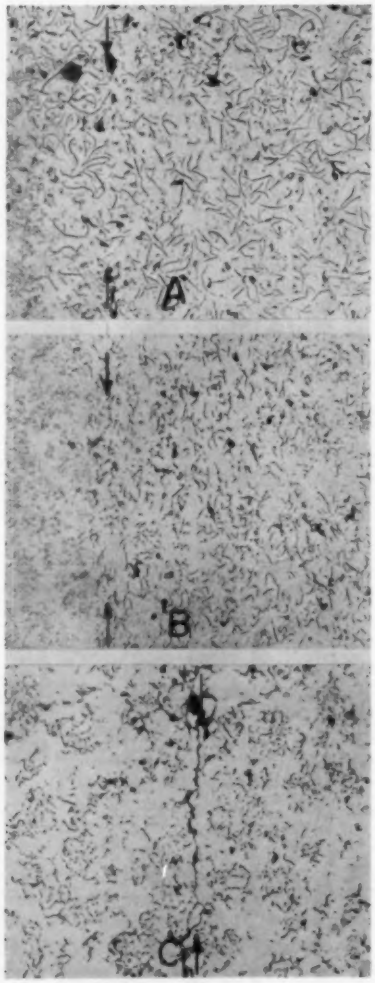

Fig. 7—Microphotograph of sections Figs. 5A (A) and 5D (B) showing the presence of graphite and its orientation (×60). A concentration of graphite may sometimes occur in the weld proper as shown in section C (× 150). Arrows indicate the weld. (Reduced 30% on reproduction)

trode dies of the welding machine. When the faying surfaces of the components contact each other so that the secondary of the transformer is short-circuited by the work piece, the platen motor is reversed; when the voltage across the dies attains a certain ratio of the open circuit voltage, the platen motor is again switched for advancing the platen.

By choosing a relay with high sensitivity and suitable dynamic properties, reliable and accurate control of the platen travel is obtained. By means of a rheostat in the relay circuit, the reversing voltage of the relay is accommodated in relation to the secondary voltage choosen so that reversing occurs at a voltage which is set at a certain ratio of actual secondary voltage.

The moment of transition from preheating to flashing is determined by the temperature of the faying surfaces. Although no short-circuit is obtained when the components are brought together, the developed heat will be sufficient to maintain flashing and the relay will keep the motor switched for advancing the platen. After a preset flashing travel has been passed by the platen, a dog will actuate a limit switch, causing the motor to increase its speed to upset speed. After a preset upset travel has then been passed, another dog will actuate another limit switch, causing the motor to be braked to standstill.

The welding current can be automatically switched off after a predetermined platen travel has been completed during upsetting, or—if desired—the current switch-off can be delayed so that a certain postheating can be obtained.

As the preheating is automatically controlled, preheating is obtained if the welding voltage is chosen below a certain value. Direct flashing is obtained if the welding voltage is chosen sufficiently high in relation to the weld section.

Since upsetting is made with a certain travel and the workpiece absorbs only the upsetting force which corresponds to this upset travel, one and the same machine can be used for welding down to very small sections from the size determined by the maximum upset force that the machine can deliver. The limitation mainly depends on the clamping devices. If they do not prevent it, the minimum weld section may be down to $^1/_{100}$ of the maximum section.

The machine settings are made on a regulator box where initial die opening, flashing travel and upset travel are preset. In the driving gear between motor and platen is incorporated a slip coupling which goes into action if, due to faulty setting or faulty operation, too high a resistance to the platen travel should arise at upsetting. In this way the motor is protected against overload. Since the slip coupling does not function under correct conditions, it can be considered as a safeguard against faulty setting.

At the beginning of the preheating period, the faying surfaces meet with rather high contact force which decreases as the surfaces are heated. During flashing the force cannot be measured. This example refers to cast iron. (The proper difference in the case of mild steel is that each preheating stroke then results in a more or less strong partial weld between the components which must be broken when the platen returns.)

To begin with, the voltage across the faying surfaces decreases for each preheating stroke as the contact is gradually improved. Toward the end of the preheating cycle, the voltage increases because the resistance increases due to the heating becomes predominant. When flashing starts, the voltage is almost equal to the open-circuit voltage. The curve for speed shows how the driving motor, which is controlled by the voltage relay, moves the platen forward and backward until flashing voltage is attained. This does not influence the relay.

At upsetting, the flashing is cut off after a moderate increase of platen speed and voltage drops when a short-circuit occurs between the faying surfaces. The voltage slightly decreases further during the upsetting. The voltage relay has now been switched off and has thus ceased to govern the platen motion.

The pressure between the surfaces begins to increase after the short circuit has occurred. This is due to the surfaces being covered with a layer of both molten material and material having very low strength in the hot condition. When this material has been squeezed out, the upset force will increase until the upset travel has been completed and will then decrease again when the shrinking begins with cooling.

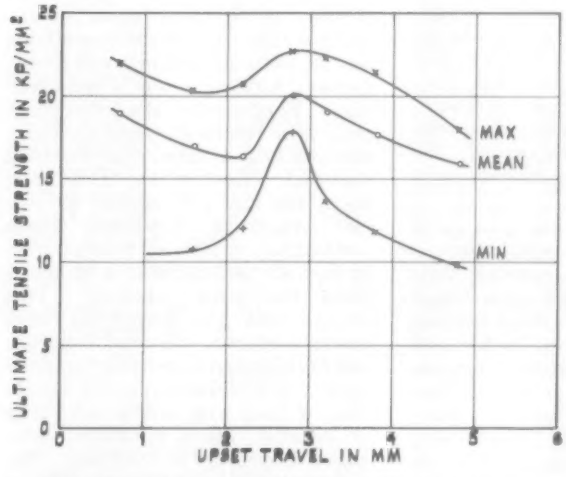

Fig. 8—Variation of the tensile strength with the upset travel. Cast iron with C—3.64%, combined carbon—0.69%, Si—2.50%, Mn—0.44%, P—0.44%, and S—0.102%

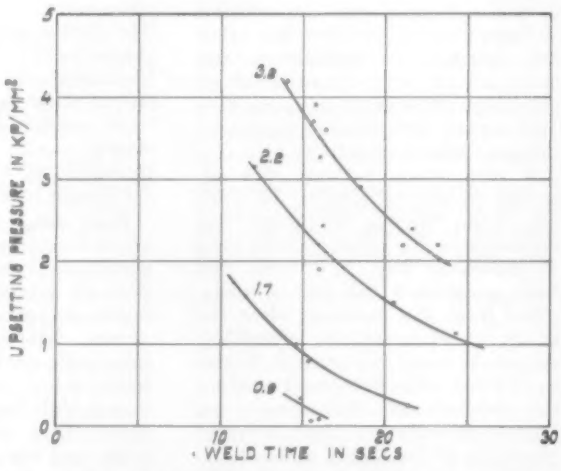

Fig. 9—Variation of upsetting pressure with the weld time at different upset travels (0.9, 1.7, 2.2 and 3.2 mm)

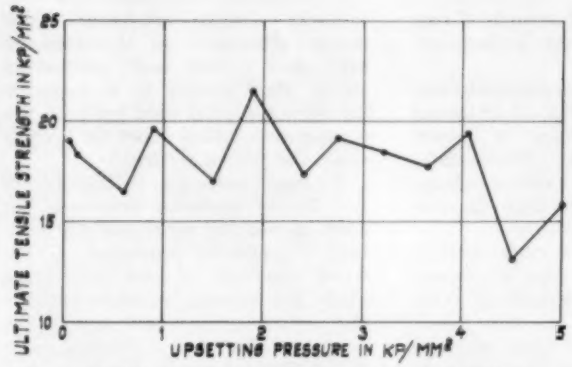

Fig. 10—Variation of tensile strength with upsetting pressure

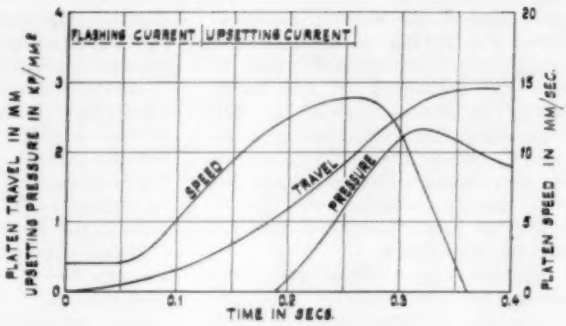

Fig. 11—Platen travel, upsetting pressure and platen speed during upsetting

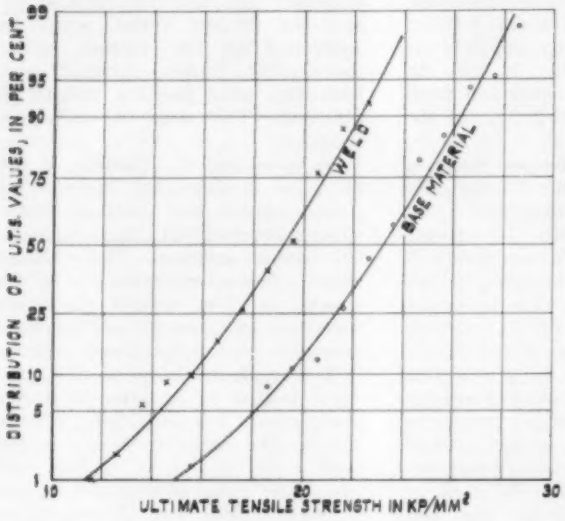

Fig. 12—Distribution of ultimate tensile strength values of base material and weld in cast iron with C—3.55% Si—2.65%, Mn—0.55%, P—0.60% and S—0.085%

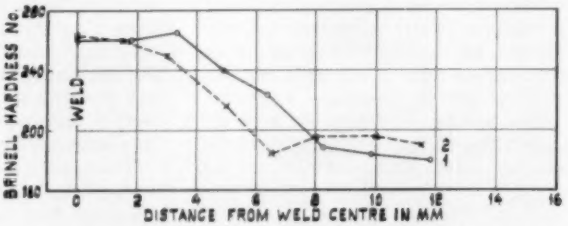

Fig. 13—Material hardness at different distances from the weld. Curve 1; C—3.68%, combined carbon—0.12%. Si—1.48%, Mn—0.38%, P—0.48%, and S—0.067%, Curve 2: C—3.64%, combined carbon—0.69%, Si—2.50%, Mn—0.44%, P—0.44%, and S—0.102%.

Physical Properties of Cast Iron and Heat-resistant High-nickel Alloys

Cast iron and high-nickel alloys are considered to be rather difficult to weld and could also be considered as extremes. Cast iron has very low deformation capability in the hot condition, while the nickel alloys have high strength in hot condition and normal deformation capability but poor heat conductivity.

A comparison between the absorbed upsetting pressure at various upset travels for these two materials and a common mild steel is shown in Fig. 3. Travel has been considered the platen movement from the moment when the speed is increased for upsetting. As can be seen, the pressure begins to develop after different travel for the different materials wherein the travel depends on the different plasticity of the faying surfaces.

The most important physical properties for the materials are given in Table 1. Mild steel and cast iron have very different electrical resistance at room temperature, but the difference in temperature coefficient causes considerable decrease at high temperature. Remaining physical properties for the two materials are rather equal. The high-nickel alloys are mainly characterized by their very low heat conductivity, their high electric resistance and very low temperature coefficient. Ultimate tensile strength and elongation of the materials at various temperatures are shown in Fig. 4.

Mild steel and cast iron have about the same mechanical strength within the temperature range 600–800° C, but the mild steel has a higher strength at increased temperatures. The curve for high-nickel alloy is greater throughout the whole temperature range. The elongation is high for mild steel and high-nickel alloy at high temperature, while cast iron has very low elongation over the entire temperature range.

The chemical composition of the cast iron and the high-nickel alloys which have been the object of this investigation is given in Table 2.

Flash Welding of Cast Iron

In the case of cast iron, flash welding is definitely more advantageous than other welding methods in that heating is uniform and simultaneous across the whole weld section. Furthermore, the rather short weld time results in relatively insignificant heat influence on the base material. Thanks to these two facts, the risk for residual stresses and cracks is decreased. Flash welding has an additional advantage in that all molten metal is squeezed from the weld junction. This means that the completed weld consists of only material that has not been heated to melting temperature. As a consequence, the formation of hard and brittle ledeburite is avoided. As a structure, ledeburite is difficult to machine. The difficulty with flash welding of cast iron is in the low plasticity of the material (also in red-hot condition).

The upsetting must, therefore, be executed with great care. All molten material must be squeezed from the weld zone, but the base material lying behind must not be deformed since cracks will otherwise occur. Setting of the upset travel is therefore critical. Figures 5 to 7 show a series of welds executed at different upset travels. When a certain upset travel is exceeded, superficial cracks occur while the enclosed inner parts can absorb high pressure without damage.

The low plasticity of the cast iron primarily stems from the graphite content. With their irregular orientation and unfavorable form, the coarse graphite flakes, which are at hand in common sand-mold castings, have an efficaciously deformation-preventing influence since the graphite has very low strength and elongation. The more uniform and finely dispersed the graphite is, the more suitable for flash welding is the cast iron. The most suitable type of graphite is found in the nodular cast iron where—thanks to special alloy additions—an almost spheroidal graphite has been obtained. The graphite behaves in the cast iron in the same manner as slag inclusions do in common mild steel, i.e., at upsetting it has a tendency to change its orientation so that close to the weld it is parallel to the fusion zone. Simultaneously, a certain enrichment occurs and, in exceptional and unfavorable cases, an almost continuous streak of graphite (parallel to and close to the weld) may be obtained and result in low strength.

Besides graphite, normal gray cast iron mainly contains three other structure members—ferrite, pearlite and phosphide eutectic. Sometimes, also, small remainings of ledeburite appear in surface layers where cooling has been rapid. Heat-affected material (e.g., by welding) may also contain martensite, troostite and sorbite.

The ferrite has an ultimate tensile strength of 35 kp/mm², an elongation of 40% ($L = 5 \times D$), and a hardness of 95 Brinell. The pearlite has much higher strength (ultimate tensile strength of 80–100 kp/mm²) with an elongation of about 15% and a hardness of 240 to 300 Brinell. Phosphide eutectic is hard and brittle and has low strength.

The various structures are due to composition and treatment of the material. Thus a high carbon content results in high graphite content, and slow cooling causes the graphite to be more coarse. This is especially noticeable for sand-mold castings with great thickness where the ultimate tensile strength becomes low. Silicon reduces the capability of the iron to dissolve carbon and, therefore, promotes graphite formation. This influence is supposed to have a maximum at about 2.7% Si. Nickel and other alloy members act in the same direction as silicon, while manganese, sulfur and chromium mainly suppress graphite formation and thus cause the formation of harder structure components at welding.

Phosphorus makes the cast iron easily fluid and is, therefore, used in iron for thin-walled castings. It appears in the structure as phosphide eutectic (steadite) with a melting temperature of approximately 200° C below that of the rest of the material and is, therefore, generally squeezed out at upsetting. Steadite, consequently, occurs to a lower extent in weld and weld-heat-affected zones than in the nonaffected base material.

The matrix of the gray cast iron consists of pearlite and a varying quantity of ferrite beside the graphite and the steadite. During welding, the matrix is completely transformed to austenite which, due to the rather rapid cooling, then forms a considerably more finely dispersed and consequently harder pearlite than present in the base material. Simultaneously, the content of free ferrite is, in general, decreased. The dissolving of the graphite requires high temperature and takes time; it occurs, therefore, only to a limited extent during welding.

In certain cases when the silicon content is very high, a formation of graphite can occur whereby carbon is absorbed from the surrounding austenite. As a result, the graphite will be surrounded by bright ferrite islands. If, on the contrary, the silicon content is low, a certain dissolution of the graphite is obtained. Here the matrix will then consist of very finely-lamrinated pearlite (sorbite-troostite) and a certain quantity of martensite, the latter depending on the cooling rate. The weld and transition zones will then be harder than the base material.

The upset travels for the section shown in Fig. 5 are (A) 0.9 mm. (B) 2.2 mm, (C) 3.2 mm and (D) 4.3 mm. Figure 6 is the same section as Fig. 5C but is etched in order to show the distribution of the steadite. As can be seen, there is almost no steadite in the center of the weld. It can, however, be found toward the surface in streaks at an angle of 45 deg to the weld. This shows that the easily fusible steadite is pressed out and concentrated at the cracking notches.

For all sections, graphite at the inside of the tube appears as large flakes, which become smaller at the outside where cooling during casting has been more rapid. Figure 7 (A and B) is a magnified view of the sections in Fig. 5 (A and D). As can be seen, the graphite flakes are arranged parallel to the weld in the case of great upset travel. Figure 7C shows that a graphite concentration can sometimes occur in the weld proper.

Table 3—Influence of Heat Treatment on the Strength of Welds in Cast Iron (Test Specimen in Numbers in Brackets)

	Ultimate tensile strength, kp/mm²	
Material quality	A	B
Base material, as-delivered	22.8 (40)	25.2 (5)
Weld specimen, preheated:		
750° C, 2 hr in furnace, cooled, welded	...	20.9 (9)
750° C in machine, welded in hot condition	...	17.6 (9)
Weld specimen, welded and postheated:		
575° C, 1 min in machine	19.3 (20)	...
750° C, 1 min in machine	19.4 (43)	...
575° C, 1 hr in furnace	...	23.0 (3)
750° C, 2 hr in furnace	...	19.2 (4)
Weld specimen, as-welded	19.4 (41)	22.5 (3)

Table 4—Welding Settings Used for Study of the Properties of the Weld Zone (16.5 Mm Diam High-chromium-nickel)

Total overhang, mm	25
Flashing travel, mm	5.0
Upset time, sec	0.54
Upset current time, sec	0.36
Upsetting pressure, kp/mm²	18–22
Weld current, amp	7600

Table 5—Welding Settings Used for Study of the Properties of the Base Material (High-chromium-nickel, 16.5-mm²)

Setting	A	B
Total overhang, mm	30	30
Flashing travel, mm	5	5
Flashing speed, mm/sec	4	4
Weld time, sec	8.5	7
Upset time, sec	0.73	0.73
Upset current time, sec	0.38	0.38
Upsetting pressure, kp/mm²	14	20
Weld current, amp	6900	6900

Strains in Weld and Base Material

As previously mentioned, the weld is subjected to strains due to the upsetting. Strains may also occur in weld and base material because of other reasons. The following four cases deserve special mention and observation:

1. *The clamping force* must be moderate welding thin-walled tubes to prevent the tubes from cracking.
2. *Deflection of the machine* due to clamping force should be kept very low, i.e., the machine must be of very rigid design. If unclamping does not occur simultaneously at both clamping devices, bending stresses could otherwise occur if one lower die rises from deflected position during unclamping while the work is still clamped in the other clamping device.
3. *Too early unclamping* can cause fracture in the weld since handling of the work piece with the weld in hot condition is dangerous because a hot weld has low strength.
4. *Bouncing of the platen* at completed upset must be avoided. Likewise, too rapid a disappearance of the upset force during cooling of the weld with the work piece in clamped position must also be avoided since shrinking may otherwise cause tensile strains.

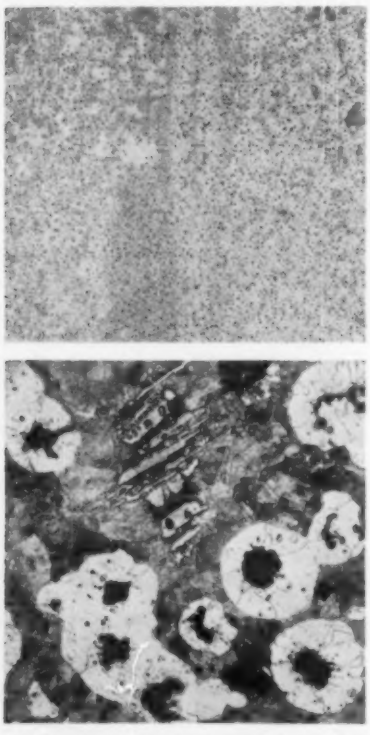

Fig. 14—Weld in nodular cast iron. Top photo shows the weld vertically through the center of the photo (× 5), while the bottom photo is taken in nonheat-affected base material × 33. (Reduced by approximately 35% on reproduction)

Evaluation of Test Results

Determination of the ultimate tensile strength of the weld is an intricate problem. The tensile test specimens must be prepared with great care, and the testing must be made in such a way that additional strains due to bending are avoided. This means, however, that the test pieces must be turned after welding. By this machining operation, a part of the surface layer, which might have been damaged and might have caused a rather low ultimate tensile strength value for the total weld section is removed.

Besides the tensile testing of machined test specimens, the determination of weld quality should also comprise macro- and microexamination of the surface layers.

During the welding of centrifugal-cast tubes, notch effects caused by damaged surface layers must be avoided although, for certain other kinds of work, a machining allowance may be added and thus permit the damaged surface layer to be removed.

As the diameter of the test specimen must be very small—8 to 10 mm or smaller—depending on the wall thickness of the tube, rather low values of the ultimate tensile strength may be occasionally obtained due to small local irregularities or slag inclusions which are insignificant in relation to the total weld section but important in relation to the particular test specimen.

Figure 8 shows how the ultimate tensile strength for machined test specimens varies with the upset travel. As can be seen, high ultimate tensile strength values for the weld may also be obtained at very short upset travel, although the values are very scattered. The curve shows minimum scatter with the highest mean value at an upset travel of about 2.8 mm. At longer upset travel, the scatter increases and the mean value decreases.

The upsetting force absorbed by the weld is—compared to upset travel—to a high degree determined by the weld time and the temperature gradient. Figure 9 shows how the upsetting force varies with the weld time at some different upset travels.

The ultimate tensile strength for the machined test specimens is not much influenced by the upsetting force as Fig. 10 shows. High strength may be obtained even at very low upsetting force. The points in the diagram represent mean values for a total of approximately 80 test specimens from the same tube quality.

The great scatter of the values is due to the tests having been made with various weld times and upset travels.

Figure 11 shows a typical upset course at welding of cast iron. The diagram shows the platen speed, upset force, and platen travel as functions of time. The moment for the end of flashing and welding current switching-off have been indicated.

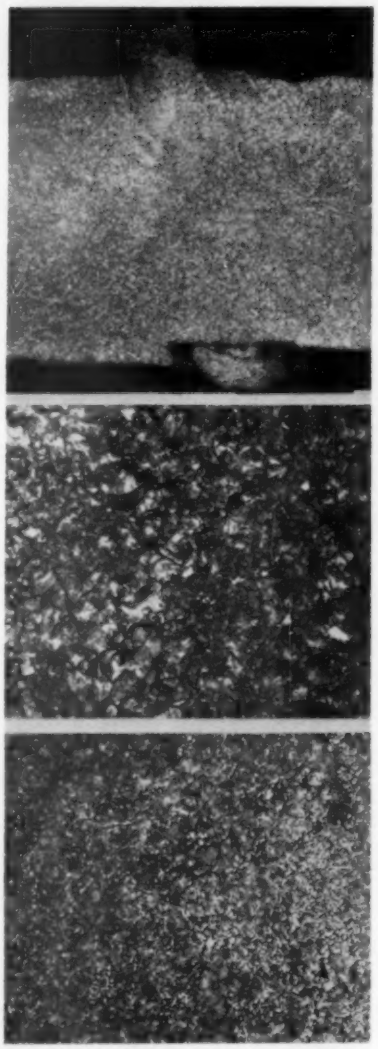

Fig. 15—A weld of very good quality made in a cast iron tube of U. S. origin with analysis: C—3.75%, combined carbon—0.61%, Si—2.03%, Mn—0.57%, P—0.23% and S—0.036%. Top—× 11 macrophoto; middle—× 150; microphoto at the outside of the tube; bottom—× 150; microphoto at the inside of the tube. Etching: Bolton. In the middle and bottom views, the weld goes downward through the center part of the photograph (Reduced by approximately 30% on reproduction)

Obviously, weld results are influenced by the composition, the manufacturing process, and the structure of the cast iron. Sometimes equal strength is obtained for the weld as for the base material, but the rather great scatter also for the ultimate tensile strength values of the base material must always be considered. Figure 12 shows a distribution diagram for the ultimate tensile strength values of base material and weld, related to a large number of specimens of the same material quality, welded with equal setting. The diagram shows that a great number of weld specimens have an ultimate tensile strength higher than the lower ultimate tensile strength values of the base material, while the mean value for all weld specimens is 83% of the ultimate tensile strength of the base material. A higher mean value for the weld strength than indicated by Fig. 12 may be obtained, and this example is chosen only to show that the result must be judged critically.

A heat treatment before or after welding may sometimes be advantageous. Correct heat treatment in advance gives the base material a more uniform hardness. Centrifugal cast tubes may vary in hardness due to differences in cooling conditions. In general, the hardness is higher at the outside of the tube than at its inside. As an example, the following hardness values measured before heat treatment may be quoted (order from inside outward): 219, 229, 244, 272, 292, and 363 Brinell. After heating at 750° C for 2 hr, the following values were measured: 158, 167, 180, 184, and 195 Brinell. The hardness can also vary along the tube so that it is harder at the ends. The material is generally homogenous, but the inner tube surface may be uneven.

Heating in the welding machine (immediately before welding and so executed that the entire part of the tube which lies between the dies attains high temperature) is not recommended as it results in a weld of inferior quality.

Welding with normal preheating does not cause any greater change in hardness—Fig. 13.

Postheating, executed either immediately after welding and in the welding machine during a rather short time or afterward in a furnace does not seem to influence the tensile strength of the weld—Table 3. Sometimes a certain relief of residual stresses in the material may be obtained; the question of heat treatment must, therefore, be judged in each specific case.

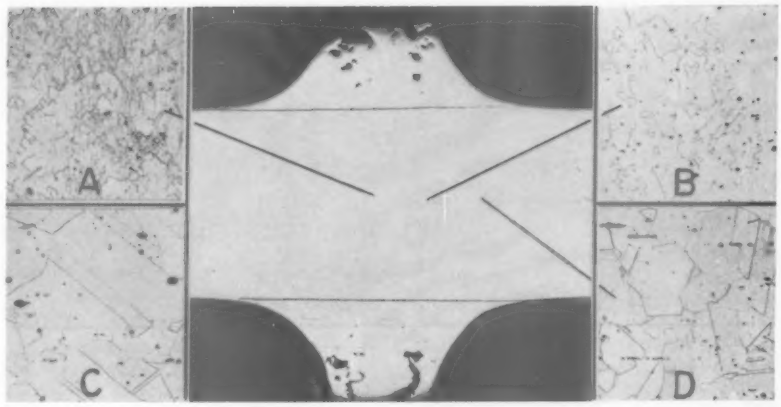

Fig. 16—Typical weld in high-chromium-nickel alloy (X 11; not etched) including microphotos (× 80; etching: Chrome-regia) of weld, section 1 mm from weld, section 10 mm from weld, and section 2 mm from weld. (Reduced by approximately 30% on reproduction)

If the cast iron is cooled rapidly at casting, it attains great hardness. The material is, however, weldable in this condition. As an example may be mentioned a centrifugal-cast tube (with a hardness in the base material of 470 Brinell) which was welded. After heat treatment through which the hardness of the base material was decreased to 187 Brinell, the ultimate tensile strength of the weld was determined at 22 to 29 kp/mm². For comparison, another tube of equal analysis but normal hardness was welded. Without any heat treatment the ultimate tensile strength of the weld was determined at 22 to 24 kp/mm², while the ultimate tensile strength of the base material was 25 kp/mm².

If the content of combined carbon in the cast iron is increased, the tensile strength is decreased. At an experiment, a centrifugal-cast tube where 16% of the carbon was present as combined carbon, was heated in a furnace at 1000° C for 3 hr with slow cooling whereby the content of combined carbon decreased to 4%. Both for the weld and for the base material the ultimate tensile strength was through this heat treatment lowered 9 and 11%, respectively, of the values for the nonheat-treated material. On the flash welding of nodular cast iron with 1.5% Ni and 0.2% Mn, an ultimate tensile strength of 40 kp/mm² was obtained after heat treatment, including normalizing at 850° C and annealing at 600° C. Figure 14 shows a section through this weld. The hardness was determined at 250 Brinell in the weld and 230 in the base material. See also Fig. 15.

Welding of High-nickel Alloys

An investigation on the weldability of high-nickel alloys has been confined to an alloy known under the commercial name Nimonic 80, and the results obtained have given ample information regarding the behavior of the high-nickel alloys of similar composition.

Experience published in technical magazines leads to the concept that it is necessary to work with narrowest possible heating zone to obtain a satisfactory result which signifies working with a very steep temperature gradient. Practically, this means using machines intended for direct or almost direct flashing (i.e., no preheating). Due to the small amount of plastic material at hand in the weld zone and the rather high deformation resistance of the material, a very high upset pressure must be applied. As an example, an upset pressure of 40 to 50 kp/mm² has been indicated for this alloy, the lower value referring to concentrated and the higher value to extended weld section. The two factors—narrow heating zone and high upset pressure—have involved the use of rather large welding machines, mainly with cam-operated or hydraulically operated upset travel.

The investigation described here was made mainly in order to study whether a motor operated machine was better suited for the actual welding problem.

To start with, tests were made with welding in accordance with previous experience whereby results reported here were established.

The actual alloy has—as already mentioned—a very low electric conductivity and, in order to eliminate the risk of burns at the transition

Table 6—Study of the Influence of the Upsetting Pressure on the Ultimate Tensile Strength and the Elongation (High-chromium-nickel, 370 mm² Weld Section—7-mm Diam Tensile Test Specimens)

Total overhang, mm	46					
Flashing travel, mm	6					
Upset travel, mm	10–12					
Weld time, sec	12–14					
Upsetting pressure, kp/mm²	15	16	18	20	22	24
Weld current, amp	9200	8600	9200	8600	8600	9200
Ultimate tensile strength,[a] kp/mm²	104.9	104.9	104.8	102.0	100.2	96.4
Elongation[a] ($L = 50$), %	25.7	23.3	22.5	20.8	18.8	17.5

[a] Mean values.

from die to workpiece, a good fitting between them must be arranged. Further, the clamping (contact) surfaces of the components must be free from oxide and other (from the electrical point of view) more or less insulating impurities.

During the welding of test specimens with pronounced corners, e.g., specimens of square or rectangular cross section, there was a possibility for superficial edge cracks in the base material, especially within the heat-affected material. This could not be eliminated by choosing another material for the clamping dies and was, therefore, supposed to depend on the shape of the workpiece only. When all corners of the test specimen were rounded with a radius of at least 2 mm, the superficial edge cracks disappeared. When the welded specimen was exposed to a bending strain, however, these edge cracks became visible again. A metallurgical examination showed also a distinct oxidation. In order to prevent any influence by the geometrical shape of the workpiece, the investigation continued with the welding of test specimens of circular cross section whereby somewhat improved results were obtained. However, really satisfactory results were obtained only after a thorough investigation had been made of the switching-off moment for the current during the upset travel. Totally in accordance with previous experience, it proved that the upset current time must be very short.

All influencing factors cooperate in such a manner that the machine setting, which produces a satisfactory result, becomes very critical. In other words, only a slight change of the machine setting or of the size of the workpiece is sufficient for hazarding the result.

Further investigation proved that the surface cracks probably were due to local overheating of the material, i.e., at the current transition areas between electrode dies and work piece. During upsetting, the current density was very high in the contact points due to the high secondary voltage generally used during welding with direct flashing.

As has been stressed, a rather high general heating is obtained during welding with preheating although the current transmitted from electrode dies to work piece is rather low. Welding tests in a motor-operated flash welding machine proved that—although the actual alloy has lower electric conductivity and lower heat conductivity than common mild steel—the heating zone should be kept longer than normally obtained by increasing the overhang.

Variation of the flashing speed proves that the best result is obtained at a moderate speed. A low speed tends to cause inferior weld result manifesting itself as an oxidation of the faying surfaces, probably due to the impossibility of maintaining a sufficient gas shield from evaporated base material. This, however, cannot be the only reason for the inferior result, because tests where the faying surfaces have been protected by an inert-gas shield (argon) did not produce a weld result satisfactory in all respects. At higher flashing speeds a tendency to burning marks and edge cracks can be observed. The reason is that a higher secondary voltage must be chosen, provided that all other factors, influencing the result are kept unaltered. Evidently the flashing must occur without any disturbance whatsoever.

The same protective measures against the formation of cracks, which have proved necessary at welding according to the previously used method, are also recommended here.

The moment of breaking the welding current during the upsetting is considerably less critical thanks to the rather low upsetting speed, and tests have shown that as a rule the current may be on during the first half of the upsetting period. Earlier breaking is to risk incomplete squeezing-out of oxides and other impurities from the welding zone, while a later breaking is to risk overheating of the weld and surrounding parent metal.

The upsetting pressures used at the tests lie within the range 13–20 kp/mm². In this connection it may be of interest to underscore that an examination of the completed weld by eye only does not give any information of its quality. As is generally known, the so-called treble-tongue upset is considered a criterion of a good weld, but this has proved not to hold good for the actual alloy. This is with all desirable distinctness illustrated by Fig. 16, which shows the typical appearance of a weld upset in high-nickel alloy obtained with a good machine setting.

The testing of weld results has been made partly in the as-welded condition, partly after a heat treatment for 8 hr at 1080° C followed by cooling in air and subsequent heating for 16 hr at 700° C.

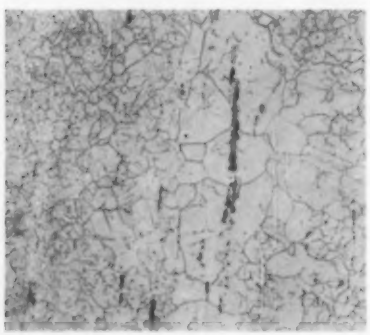

Fig. 17—High-chromium-nickel, base material 10 mm from weld, heat treated. Electrolytic etching in oxalic acid. × 80 (Reduced by approximately 35% on reproduction)

Fig. 18—Weld zone in high-chromium-nickel (indicated by arrows). Electrolytic etching in oxalic acid. × 80. (Reduced by approximately 35% on reproduction)

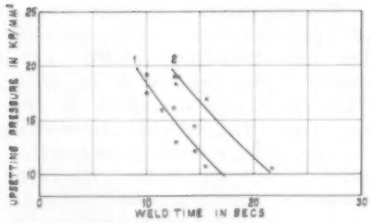

Fig. 19—Relation between upsetting pressure and weld time for an upset travel of 10 mm (Curve 1) and 12 mm (Curve 2)

The tests have been examined with regard to bending, tension, creeping and structure.

Table 4 gives an account of welding tests in 16.5 mm. diam high-nickel alloy. Specimens tested with regard to tension strength in as-welded condition fractured—as usual—in the weld zone at an ultimate tensile strength of approximately 75 kp/mm². The appearances of the fracture surfaces did not give any information.

Specimens bent 180 deg across a mandrel of 30-mm diameter showed no tendency to crack formation.

Specimens heat treated according to the program specified earlier were metallographically examined. Figure 17 shows a section through the base material 10 mm from the weld, while Fig. 18 shows the weld zone horizontally. Both show that the grain size in the weld zone is mainly the same as in the nonheat-affected base material. Further, it is distinctly visible how the streaks of titanium nitride by the upsetting have been bent out toward the surface (below, at the right).

A series of tests were made with the settings quoted in Table 5. Welds performed with setting A and exposed to tensile testing after complete heat treatment showed fractures in the base material at 105 to 110 kp/mm². It should be observed that the upsetting pressure was only about 14 kp/mm². Creeping tests on completely heat-treated specimens also resulted in fracture in the base material, after equal time as for nonwelded base material.

Specimens welded according to setting B were tensile tested in as-welded condition. Fracture occurred in the weld at about 77 kp/mm². The fracture surfaces did not show any defects whatever. Creeping tests on material, welded with exactly the same data and heat treated, fulfilled the requirement of time to fracture (for the actual alloy, minimum 75 hr at a stress of 29.9 kp/mm²), but the fracture appeared partly in the weld after about the time required for non-welded material. A metallurgical investigation showed in the transition zones a recrystallization with finer grain size than in the base material (magnitude about 50%). This is probably due to the upsetting pressure used (20 kp/mm²).

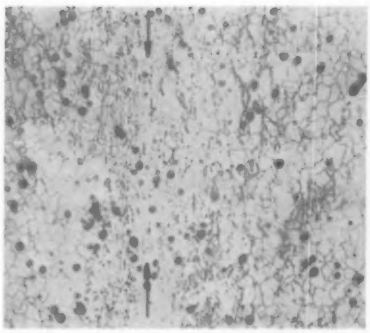

Fig. 20—Section showing cold deformation of weld zone (weld indicated by arrows). No heat treatment. Electrolytic etching in oxalic acid. × 80. (Reduced by approximately 35% on reproduction)

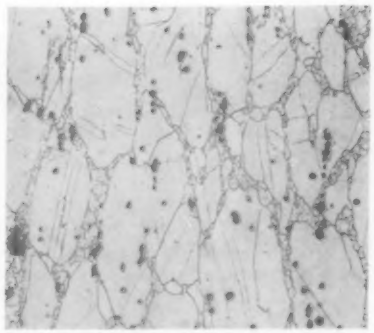

Fig. 21—Base material 10 mm from weld, only slightly heat affected. No heat treatment. Electrolytic etching in oxalic acid. × 80. (Reduced by approximately 30% on reproduction)

In order to study the influence of weld time on upset pressure some tests with material of 300 mm² cross section were carried out. The results are indicated in Fig. 19. The curves distinctly show how upsetting pressure varies with weld time for the setting used. Because the upsetting pressure has a determined influence on the weld strength, it can be seen from the curves that the weld time must be kept within rather narrow limits.

When looking at strength values for nonheat-treated specimens, one is struck by the fact that the tensile strength seems almost constant despite differences in both weld time and upset travel. A certain explanation is the cold deformation obtained in the weld zone proper. This is illustrated by Fig. 20, which shows the weld zone vertically. The base material at such a small distance from the weld as 10 mm (Fig. 21) shows, on the contrary, only a slightly heat-affected structure. It ought to be mentioned that the black spots, visible in the illustrations, consist of titanium nitride which has been exposed to attack during polishing.

A specimen welded with the same setting as in Fig. 20 and heat treated is shown in Figs. 22 and 23. Figure 22 gives a clear evidence of what has been stated earlier regarding grain size in the transition zones while the weld zone (horizontal as illustrated) is distinctly visible due to the considerably coarser grain size. Figure 23 shows the base material at 10 mm distance from the weld.

It is obviously of great interest to study if the machine settings may also influence the strength properties of welds which are good in all other respects. For this purpose tests were made as indicated in Table 6. It can be clearly seen

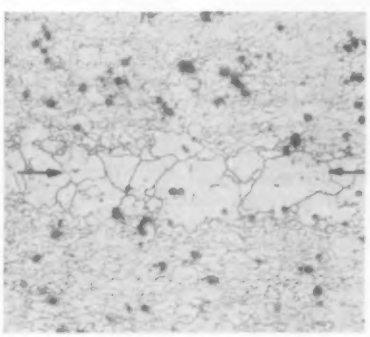

Fig. 22—Weld zone in heat-treated material (weld indicated by arrows). Electrolytic etching in oxalic acid. × 80. (Reduced by approximately 30% on reproduction)

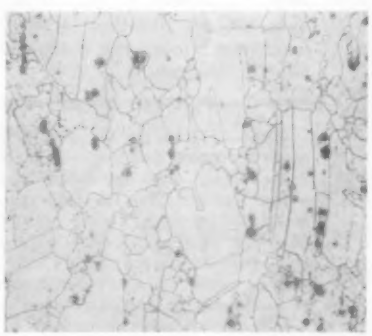

Fig. 23—Base material 10 mm from weld, heat treatment. Electrolytic etching in oxalic acid. × 80. (Reduced by approximately 30% on reproduction)

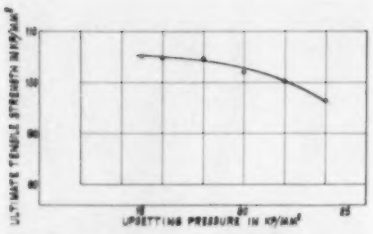

Fig. 24—Ultimate tensile strength in relation to upsetting pressure

that the upsetting pressure obtained is influenced by the heat brought into the material during welding.

As can be noted, both ultimate tensile strength and elongation increase with decreasing upsetting pressure. The explanation hereto is probably the decrease in influence on the grain size which is obtained with decreased upsetting pressure. The relation between ultimate tensile strength and upsetting pressure is given by Fig. 24.

The investigation shows that, with motor operated flash welding units, very good results can be obtained in welding high-chromium-nickel with an upsetting pressure which is considerably lower than that recommended for other types of flash welders. In spite of the considerably lower upsetting pressure, other influencing factors will not be more difficult to set. However, as a matter of course, due consideration must be given to the extremely low heat conductivity and high electric resistance of the material.

Conclusion

Results of the investigation described here seem to prove that close control of temperature conditions and upset travel improves the flash welding of cast iron and heat-resistant high-chromium-nickel alloy. If upset in the case of cast iron is made so as to maintain a certain plasticity in the weld zone immediately after completed upset, the risk of destroying the structure in the transition zone is eliminated. As a consequence, there is no risk of cracks or cold upset.

With high-chromium-nickel alloy, overheating and superficial cracks seem well under control when using flash welding.

The importance of close control of upset travel and upset pressure has been stressed in another document[3] which appeared in 1960. The experience described in this document, dealing with the welding of segregating steel strip, proves that short upset travel, low upsetting pressure, and moderate upsetting speed are also advantageous for steel strip which presents difficulties similar to those presented by cast iron and the high-chromium-nickel alloy.

Acknowledgments

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Bibliography

1. Document IIW/IIS III-59-56: Recommendations for Flash Welding.
2. Document IIW/IIS III-68-56: Recommendations for Flash Welding with Preheating of Non-alloyed Steel with C Max = 0.4%.
3. Nakamura, T., Yamaguchi, T., and Hamasaki, M., Document IIW/IIS III-137-60: Flash Welding of Segregating Steel Strip.

Welding Type 347 Stainless Steel Piping and Tubing

By George E. Linnert

A book of 103 pages with paper covers 8¼ in. by 11¼ in. Price $3.50. Known as Bulletin No. 43. Single copies may be purchased through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y. Quantity lots may be purchased through the Welding Research Council, 29 W. 39th St., New York 18, N. Y.

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More recently, difficulties of greater consequence have been reported, particularly in connection with piping and tubing of Type 347. Accounts of trouble have come from several fields of activity and these reports, as might be expected, have alarmed many engineers. Some now seriously question the continued use of Type 347 steel in new and important applications.

This report, prepared under the auspices of the Welding Research Council, is a comprehensive review of information on the welding of Type 347 stainless steel piping and tubing. Both published and previously unpublished data are included. An account is given of the origin and development of columbium stabilized stainless steel to provide familiarity with the actual chemical composition of the Type 347 grade as it is currently produced. Facts are supplied on microstructure and properties of wrought material, castings and weld metal which later help explain the properties of welded joints. The main portion of the report is devoted to welding procedures and joint properties. Welding defects are thoroughly covered as to cause and cure.

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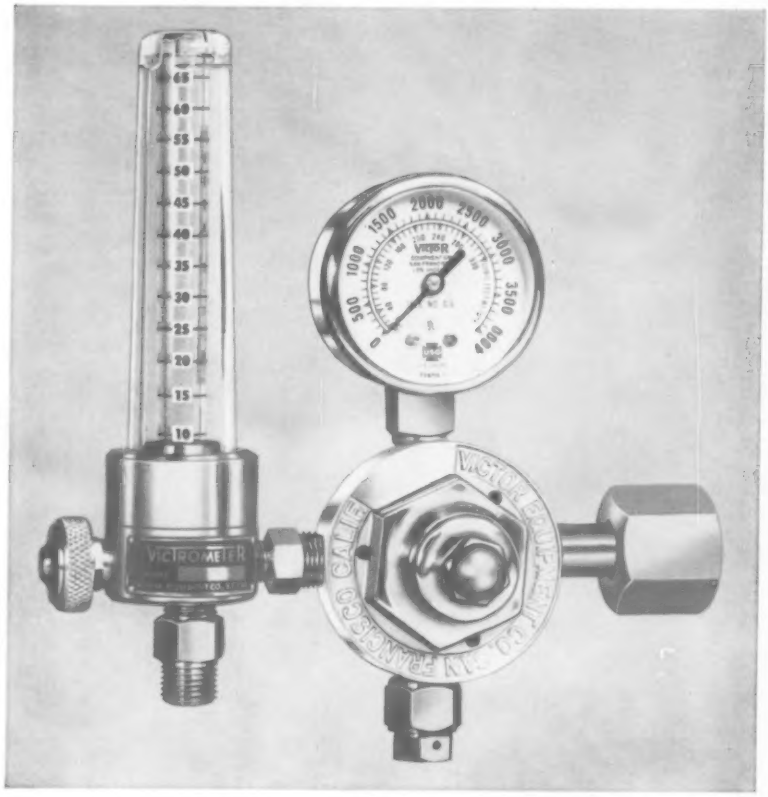

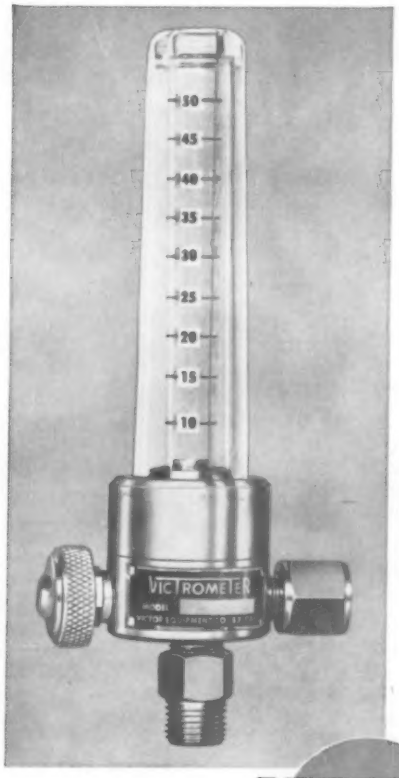

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